Institute of Terrestrial Ecology

1974

Natural Environment Research Council

Institute of Terrestrial Ecology

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The cover shows: top left, interior of a laboratory at Monks Wood Experimental Station; top right, Brown hairstreak butterfly (*Thecla betulae* L.): bottom left, Furzebrook Research Station; bottom right, Merlewood Research Station.

Contents

The role of ecology in policy making

Any organization must have a reason for existing. It is natural to begin this first Report by asking why we have an Institute of Terrestrial Ecology (ITE).

Our Institute was created as a consequence of two major decisions. The first, by Parliament, was that wild life conservation policy in Great Britain should be the responsibility of the Nature Conservancy Council (NCC), established in November, 1973, as an independent statutory body whose members are appointed by the Secretary of State for the Environment.* The second decision, taken by NERC,† was that ecology, as an important branch of environmental science, needed the continuing attention of a research institute. Accordingly the research scientists of the former Nature Conservancy who remained with NERC, with the valuable addition of the Council's Institute of Tree Biology and the Bryology Project Group transferred from the British Antarctic Survey, have been fashioned into the ITE. These new arrangements are evidently compatible with, and might have been made inevitable by, Lord Rothschild's report on Government supported research and development,‡ the NCC being a customer for ecological knowledge to guide its policies, and ITE within NERC having contractor capabilities. The second section of this Report explains how we have set about structuring the new Institute.

But this is history and by itself provides only partial justification for having an Institute of Terrestrial Ecology. If scarce public money is to be spent on a research organization concerned with the ecology of the land and freshwater environments, the case must rest on the value of such research in guiding national policy. Britain needs a research institute like ITE because we need ecological understanding if we are to use our environment wisely. In a small, densely peopled island, with many competing demands on the land, the need for such understanding is especially great.

How do ecologists contribute to wise land-use policies? Ecology as a science is concerned with interrelationships between living things and their environment. It seeks to discover why plants and animals live where they do; explores the factors which determine their numbers; describes the changes that the vegetation and fauna are undergoing and develops ways of predicting what is likely to happen in the future, if climate or human activity change in various possible ways. The objectives of the Institute of Terrestrial Ecology, developed in accordance with Natural Environment Research Council guidelines and endorsed by the Council, have accordingly been defined as:

'To improve understanding of the factors determining the structure, composition and processes of terrestrial ecological systems and the abundance and performance of individual species and organisms.

To provide a sounder scientific basis than is presently available for predicting and modelling future environmental trends, especially those resulting from man's activities, hence permitting a more critical assessment of the need for, and likely benefits of, specific measures to protect and manage the environment.'

Barbara Ward and Rene Dubos begin their book 'Only One Earth', written as a background to the 1972 United Nations Conference on the Human Environment at Stockholm, with the statement that man inhabits two worlds. One is the natural world of rock, soil, climate and landscape within which we and several million other species evolved. The other is the man-made world of urban and industrial civilization which has allowed people in many countries to free themselves from the vagaries of environmental change.

The thinking of people in developed countries is dominated by the built environment. Of course the countryside is recognized as a source of food, though there is widespread ignorance of the workings of the agricultural industry, and many people are more concerned with the packaging of food than with its production, like the small town boy who protested because the milk he drank in the country came from a nasty smelly cow instead of a sterile, predictable bottle. But the predominance of the built environment in our thinking is shown by the rapid growth of emphasis on recreation in the countryside: on farmland as a place to play in: of a rural landscape as something to be cherished for its wild life and visual beauty rather than as the support of life itself. The crude, hard fact is that technology may have cushioned us against the vagaries of the natural world, but it has not reduced our dependence on it. All life, including all human life, remains utterly dependent upon the fixation of the sun's energy by green chlorophyll pigment in plant leaves, and its use to combine water and carbon dioxide to provide carbohydrate and replenish atmospheric oxygen. This carbohydrate is the energy source that drives the whole living system of the world. Without green plants we should starve.

The productivity of plants has limits imposed by the amount of solar radiation falling on the earth, the extent of the leaf area on which the sunlight falls, the efficiency of the photosynthetic process, and the water and nutrients available to the plants. The process is not

* Nature Conservancy Council Act, 1973

† See Natural Environment Research Council Annual Reports, 1972/73 (pp 20–22) and 1973/74 (pp 14–16)

‡ *Framework for Government supported Research and Development.* Cmnd 5046

very efficient in the conversion of energy. About 5% of the sun's energy falling on the earth's surface is absorbed by green plants on land or in the sea. Only 1% of that (or 0·05% of the total incident energy) is converted into carbohydrates – of which only a small proportion is in a form suitable for animal or human food. The conversion of plant matter to the meat of a herbivore, or the flesh of a herbivore to the tissue of a predator, is also relatively inefficient. Agriculture has done much to improve the productivity of crops and livestock, but basic ecological constraints remain, and we must understand them if we are to meet the challenge of mounting demands for food in a world that is already hungry, and where populations are growing.

Natural ecological systems still exist in all the seas and much of the dry land in the world. Like agricultural and forest crops, these systems trap sunlight, form carbohydrates, pass these along 'food chains' to herbivores and carnivores, and cycle oxygen and carbon and nutrients like phosphorus, nitrogen, sulphur, calcium, potassium and other metals. As leaves fall and creatures die, the nutrients they contain are broken down by soil animals, fungi and bacteria and made available again for new growth. Natural systems of plants and animals also have a degree of resilience and stability which is, within certain limits, related to diversity. In a complicated natural system with many component species, interacting in ways that have evolved over long periods, there is considerable competition. If one species is thinned in numbers by disease or predation, there are generally other competitors with a comparable way of life to take its place. If a species increases, disease, malnutrition, parasites and predators consume the surplus. Outbreaks in which single species suddenly become super-abundant are rare in such systems. Natural cycles, interactions and food chains form that shifting equilibrium that we call the 'balance of nature'.

The history of human land-use has been one of increasing alteration in such natural balances. Forest clearance is a normal prelude to agriculture, because whatever his arboreal ancestry, man is now ill-fitted to crop tree canopies; and the kind of plants our digestive system can cope with, and the kinds of livestock we use to convert the plants we cannot eat directly, mostly belong to the ground layer. Forest clearance is commonly accompanied by loss of nutrients from the dead trees and the soil – maybe as much as ten times the level of nutrient washed out from uncleared forest.

Ecologists are concerned with the effects of these activities on the natural environment, and with the establishment of principles that may guide essential development in an ecologically sound way. They are also concerned with the environmental effects of improved modern agriculture. Modern cropping systems, with the removal of produce from farmland to cities, create a flow of nutrient from soil to crop, crop to sewer, and sewer to sea. To maintain production, those nutrients have to be restored in fertilizers. Other ecological problems arise where agriculture substitutes systems that are more productive of the kinds of food our digestions can tackle, at a cost in terms of diversity and inherent ecological stability. If you grow thousands of acres of a single plant, keeping the earth bared between each cultivated stem, other plant invaders (weeds) will naturally seek to colonize the gaps and insects and other consumers of the crop plant will find much bounty. Herbicides, intensive cultivation and pesticides are needed to protect the crop. Once the natural balancing factors are removed, man has to replace them by his own management effort.

Modern intensive agriculture depends on an input of non-solar energy (mostly from fossil fuels) to produce the machinery, fertilizers and pesticides without which it could not be sustained. Sometimes this intensive management leads to side-effects or to changes in the natural environment which are of ecological interest and concern. Some writers have described these effects in language that suggests that 'ecology' and 'agriculture' have become things apart, and equated the former with wild life, natural systems, and their conservation and the latter with industrial man's rape of the earth.

This is a dangerous fallacy. Dangerous for two reasons. First, it mis-interprets ecology and under-values the contribution ecologists can and should make to the wise development of the earth's resources. Second, it ignores the fact that agriculture is, in itself, an applied form of ecology (and indeed was an established discipline long before ecology became a science). Many ecological concepts are derived from agriculture. Agriculturalists have derived the improved strains of crop plants and livestock to which we owe much of the enhanced food production in the 'green revolution'. They have developed sophisticated crop protection methods. They have learned how to use fertilizers and irrigation so as to greatly enhance growth. But these processes are all manipulations of basic ecological features common to natural and derived systems: nutrient cycles and water supply from the soil, competition and its effects, and causes of mortality, impaired growth or reduced reproductive success.

The agriculturalist and the forester are both ecologists. The difference is that they are in the front line of practical development and application, while the 'basic' ecologist seeks to learn from a wider range of situations, and from more complex systems. In natural or semi-natural systems the full play of environmental and biological variables is manifest, interacting with the genetic material of hundreds of thousands of species from which the handful of improved strains we crop were derived. The ecologist can aid the agriculturalist by studying a broader system. The agriculturalist and the forester apply the discipline of technical and economic feasibility and social preference. Both interact and draw on the same pool of theory.

The Institute of Terrestrial Ecology is concerned with ecology as a basic science. Our aim is to do research that will be useful to those deciding the policies for the use of land in Britain. We seek to support wild life conservation through the Nature Conservancy Council, forestry through the Forestry Commission, agriculture through the Agriculture Departments, and land use planning in Central and Local Government. All of these groups of customers are users of basic ecological knowledge. They interpret this knowledge and blend scientific with economic and social considerations in order to support particular areas of public policy. Because of ITE's inheritance from the Nature Conservancy, our links are closest with those engaging in wild life conservation as a form of applied ecology, and the majority of our staff remain personally dedicated to the support of conservation – not in a narrow, protectionist sense but in the wider context of wise use of the land so that it is as productive as possible, but also beautiful, varied, and the home of a great diversity of wild plants and animals. We also have a continuing tradition of research on the basic biology of trees, which is aimed at supporting foresters both in the growing of commercial crops and in planting trees as an 'amenity' on which so much of the beauty of both urban and rural areas depends.

We can support agriculture, perhaps, particularly in the wilder, less productive and less tractable habitats. About half of the surface of Britain – and virtually all the uplands – is covered by vegetation which, though altered by centuries of use, is composed entirely of 'wild' plants. The uplands cover maybe a quarter of our land but produce only a few per cent of our food. Their soils are thought by many to have been impoverished by mis-use. All soils contain complex fauna and microflora of wild species and on these, the decomposers, depends much of the fertility of the land. Much too, depends on the extent to which nutrients, drawn up by plant roots and deposited in litter at the soil surface, are re-incorporated by invertebrate animals in the upper soil layers. The character of the vegetation in turn depends on the extent to which it is cropped by domesticated and wild herbivores – sheep, cattle, deer, grouse or insects. The kinds of ecologist we have in ITE, working in partnership with colleagues in agriculture, forestry and wild life conservation, may be able to contribute new understanding of the basic processes of the uplands, and guide their wiser and more productive use.

What it comes down to is this. There is a range of 'ecological options' for the use of any area. A tract of upland might, for example, be used most wisely as grazing land under existing or newly domesticated herbivores (staff of the Rowett Research Institute and the former Nature Conservancy have demonstrated that Scottish Red deer are not to be despised as meat producers on coarse West Highland ranges); as land most likely to be productive under trees; as land whose productivity of grasses palatable to stock can be improved; as land remarkable for its biological features and accordingly meriting conservation for wild life or public enjoyment; as land likely to erode and deteriorate still further if changed in any way; or as land so run down by mismanagement as to need a century or so under natural woodland or herbage for its soils to recover; or some combination of these and other uses might be feasible. Such options can be stated by ecologists.

We have other contributions to make as well. Biological systems are not static. Left alone, most temperate-zone grassland passes to scrub and thence to forest. Lakes fill with silt, and reeds and fen push out from their shores, ultimately to fill in or raft over the whole, and, with steady upward accumulation of peat, form a foundation for forest. The ecologist can chronicle how the vegetation and fauna of Britain is changing and knowing something of the conditions of life of the component species, predict the likely patterns of the future. Such biological surveillance can be valuable as an indicator of the unwelcome effects of human impact through pollution: the disappearance of many lichens from industrial regions is an indication of how air pollution has affected these particularly sensitive plants and similar changes among wild species may well alert us to hazards hitherto undetected. It was the deaths of over twelve thousand seabirds in the Irish Sea in the autumn of 1969 that really alerted us first to the possible side effects of polychlorinated biphenyls – a valuable class of industrial materials used since the 1930's. Those substances are no longer used in Britain under conditions which could lead to environmental contamination. However there may be other substances coming into use which, despite careful screening, have unexpected side effects. Can we develop a system of 'biological indicators' that will, in the future, give us early warning of such problems and so avoid costly damage or equally costly changes of industrial policy?

Ecologists too, can help the planner – or the developer – by surveying and assessing the biological features of an area whose use might be changed, and then predicting the outcome of various possible patterns of development. This is no more than a refinement of the evaluation of 'ecological options'. But there are also more positive and creative opportunities. Looking at the habitats that development might create, ecologists should be able to advise on management to produce a desired end-point, for we ought to be able to forecast the habitat conditions sufficiently to match these to the plants and animals likely to thrive in them.

The Institute of Terrestrial Ecology will continue to support the Nature Conservancy Council with research that the latter requires in order to discharge its statutory functions of wild life conservation in Britain. The kind of understanding we need if we are to state the ecological options for a piece of land, explain the changing abundance of species and vegetation types, and predict future trends, is equally important to NCC in their work. The wild species NCC seeks to conserve make up the ecological diversity of Britain. Both organizations have a vital professional interest in them.

The Natural Environment Research Council's scientific expertise, of which the expertise in the Institute of Terrestrial Ecology is only a small part, spreads across the whole field of the environmental sciences. NERC seeks to describe the environment of Britain, explain why it is as it is, predict how it will change, and guide those responsible for policy decisions by giving them the basic scientific knowledge needed to make wise choices. ITE within NERC can and must provide the basic knowledge of the biological systems of the land environment and – with colleagues in the Freshwater Biological Association – the freshwater environment also. It is not our role to advocate particular policies: the policy decision in any event must balance ecological, economic and social factors and we do not have expertise in all these fields. It is our task to ensure that the ecological factors are soundly defined and presented to the policy maker in a form he can use.

The Government White Paper on Research and Development set out to ensure that research supported by public funds was more useful to policy-makers in central Government Departments, and hence employed national resources more wisely. In ITE, as in all NERC Institutes, we are redeploying our manpower and skills to meet these needs. It is clear that we should not expect the policy-maker only to commission fundamental research, or investigations taking many years to carry out. However there is a need for basic and long-term research: no-one can doubt that. The funding of such research is more appropriately financed by funds coming to our Research Council through the Department of Education and Science. Customers must be expected to need more down-to-earth studies, and also short-term evaluations of the great amount of information we already have. The scientist cannot expect to help the policy-maker unless he not only gathers the right information, but is able and willing to present it to the user in the form, and on the time scale, the user needs. Policy decisions cannot wait for ten years of esoteric investigations. Nor is the scientific paper a convenient format to lay on the desk of a busy Minister. In ITE, we shall seek to develop a facility for desk studies and reviews of relevant areas of ecology, presenting short reports that are designed to illuminate the issue under consideration. We see this capability as a counterpart to our basic research, and in no sense an unworthy or contradictory activity.

Looking ahead, the Institute of Terrestrial Ecology, as one of a family of NERC Research Institutes spanning the environmental sciences, is seeking to acquire information about the land of Britain that is penetrating in its scientific content, illuminating in the understanding it gives us of the way of life of the plants and animals with which we share these islands, but above all, relevant to the basic choices we must all make about the management of people and land together. We can only do this in a dialogue with users of ecological knowledge – especially planners, at central and local Government level, agriculturalists, foresters and conservationists. We look to them to tell us where they need ecological information, and to devise with them ways of providing it. The staff of the Institute make two kinds of contribution to this national need. First, and rightly foremost, they work within the organization to produce the research and advice which is the Institute's reason for existence. But they play another part. As members of professional associations which are truly nationwide, and in many cases international, they help to develop the collective understanding of the world's environmental scientists. Through contributions to professional societies and through collaboration with colleagues in Universities in the training of students at undergraduate and postgraduate level they can greatly influence the development of ecology as a science. The Institute continues to value and support this wider activity of its staff.

Indeed, it is our policy to contribute where we can to the whole international environmental field whose development has been one of the most encouraging features of the recent gloom-shadowed years. The former Nature Conservancy made a major contribution to the International Biological Programme, which has done much to deepen our understanding of the working of ecological systems, and ITE staff are still evaluating the results of the Programme. With the support of the Ministry of Overseas Development, we are doing research on the propagation and growth of West African timber trees. We are now deeply involved in the Man and Biosphere Programme of UNESCO, which is in some senses a successor to IBP. Within the International Council of Scientific Unions – the world forum for professional science – we are contributing to the work of the Special Committee on Problems of the Environment (SCOPE). All these scientific initiatives are aimed at deepening our understanding of the workings of the planet, and improving its development and wise management. In this the world-community of nations must take collective policy decisions, and the newly constituted United Nations Governing Council administering the UN Environment Programme is the forum for the discussion of such policies. If I may be permitted to end this first contribution to an ITE Report on a personal note, writing as one who had the privilege of representing the United Kingdom at three of the Preparatory Committee meetings prior to the 1972 Stockholm Conference, attending that Conference, and being in 1974 Vice President of the Governing Council of UNEP, I am greatly heartened by this increasing international debate about the world's environment, and how we should manage it. There are major decisions to be taken – and these decisions must depend on a great degree of mutual understanding between developed and developing countries. They must also be founded on good science – science which, in the international as in the national context, provides the rigorous, politically neutral foundation for policy decisions which must naturally take account of human values and social priorities as well as science. Ministers have several times offered, in speeches at Stockholm and at the UN Governing Council for the Environment, to make such professional expertise as we have in this country available to the world community. In the Institute of Terrestrial Ecology, as elsewhere in the Natural Environment Research Council, we shall do our utmost to implement these promises.

M. W. HOLDGATE

Director

Section II

Organization and management of the Institute

The basic structure

Organization for its own sake has little merit and, in scientific research, administrative tidiness is no substitute for intellectual creativity. The aim of ITE organization is to make it easier for the staff of the Institute to do good research, follow creative careers, and respond individually and collectively to the national need, whether this need is for fundamental scientific study or for projects designed to service ITE customers. Because finance and manpower are limited, it is also necessary to operate with as small a headquarters and administration as possible, devoting the maximum of the resources to the research which justifies our existence.

When NERC considered how to organize the new Institute for Terrestrial Ecology it opted for a unified structure, increasingly closely knit in policy and organization. In other words, although ITE staff are based at a series of laboratories spread from Aberdeen to the south coast of England and from East Anglia to the north-west corner of Wales, these laboratories are not autonomous and are not the main components in the organization. The stations are valued facilities, giving access to a wide range of ecological situations: indeed almost the full field of ecological variation in Great Britain can be examined from these laboratories, when taken together. They are naturally the intellectual homes of the people who are based in them, and they have their own distinctive *esprit de corps*. But most are too small to sustain the numbers of people needed to cover the full range of ecological problems with which ITE must be concerned, and the very fact of their dispersion means that no one station can cover the full range of variation within Britain.

As an alternative, the main components of ITE are the Divisions and Subdivisions based on primary professional disciplines and organized to bring the whole resources of the expertise in a particular scientific field to bear in an integrated fashion. From these Divisions and Subdivisions, multidisciplinary Project Groups will be assembled to deal with problems which, as ecological problems commonly do, concern many kinds of plant, animal and environmental circumstances and demand a corresponding breadth of response. Being problem-linked, such Project Groups tend to be more ephemeral than the permanent Divisions and Subdivisions: as particular problems are resolved, staff may find themselves re-grouping to meet a new challenge, and, as careers develop, the system permits people to alternate periods of more individual and fundamental research with periods of teamwork, or periods devoted to applied research for a customer.

The basic structure of the Institute is summarized in Figure 1. It is akin to a tripod with the Director, Deputy Director and Divisional Heads as the apex. One leg of the tripod represents the structure of Divisions and Subdivisions, to one of which all scientific staff are assigned. Another leg represents the project group system. The third leg is the administrative support system, headed by the Institute Secretary who leads the Headquarter's administrative team and the local administrative staff under the Station Secretaries. In the following paragraphs, the working of these three components is explained.

Figure 2 summarizes this Divisional and Subdivisional structure, and the allocation of staff to the Subdivisions is set out in Section V. This figure also reveals the special position of certain senior officers who are wholly engaged in research in which they are especially expert. Such officers are not assigned to Subdivisions, but work directly to Divisional Heads with whom they agree their project plans.

The Heads of Divisions and Subdivisions are responsible for the professional leadership of their staff throughout the country. They give guidance on the development of project plans and advice on the presentation of results, to ensure the quality of Institute publications. The Heads of Subdivisions naturally cover a narrower field than Divisional Heads, and deal with matters of greater detail: they have special responsibility within the frameworks agreed with Divisional Heads for establishing Subdivision programmes or themes which define the priority fields of action for the Institute in the various scientific disciplines and give a context to the individual projects.

The research axis: projects and project groups

There is nothing unusual in the fact that all research in ITE is planned in advance, and that the salient details of this research are set out in Project Plans, including the background to the study, its objectives, the criteria against which its success may be judged, the methods to be employed, and the resources of manpower, supporting services, instrumentation and time required. The plans meet two needs: that of management as a means of apportioning resources according to both the potential of a proposed study and some overall scheme of priorities, and that of customers for adequate definition of how the work they commission is to be conducted. Naturally, not all research is equally susceptible to advance planning in detail and room has to be found for opportunities: project plans are envisaged as aids to clear thinking and sound use of resources, not straitjackets. They will vary in content and detail accordingly. They will, however, all have two components: a statement of the

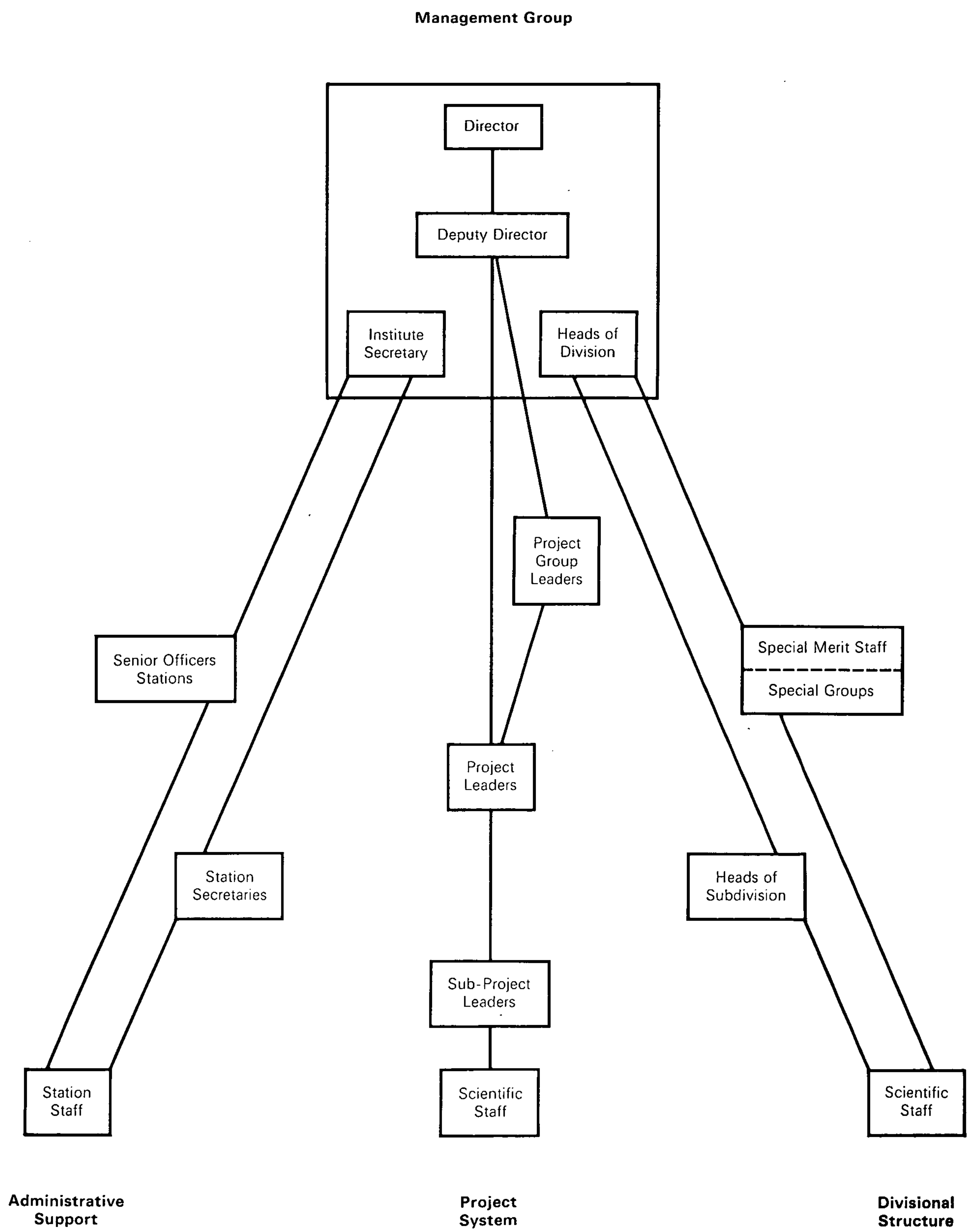

Figure 1 Basic staff structure in the Institute.

- Director
  M. W. Holdgate
  (Cambridge)
  - Deputy Director
    J. N. R. Jeffers
    (Merlewood)
    - Institute Secretary
      J. G. Ferguson
      (Cambridge)
    - Head of Division of Animal Ecology
      J. P. Dempster
      (Monks Wood)
      - Head of Subdivision of Vertebrate Ecology
        D. Jenkins
        (Banchory)
      - Head of Subdivision of Invertebrate Ecology
        M. G. Morris
        (Furzebrook)
      - Head of Subdivision of Animal Function
        R. K. Murton
        (Monks Wood)
      - *SPSO Special Merit*
        - Grouse and Moorland Ecology
          A. Watson
          (Banchory)
        - Heathland Social Insects
          M. V. Brian
          (Furzebrook)
    - Head of Division of Plant Ecology
      F. T. Last
      (Edinburgh, Bush)
      - Head of Subdivision of Plant Biology
        S. W. Greene
        (Edinburgh, Bush)
      - Head of Subdivision of Plant Community Ecology
        A. J. P. Gore
        (Merlewood).
      - Head of Subdivision of Soil Science
        O. W. Heal
        (Merlewood)
      - *Special Groups*
        - N.W. Wales Ecology
          R. E. Hughes
          (Bangor)
        - Air Pollution
          K. Mellanby
          (Monks Wood)
    - Head of Division of Scientific Services
      J. N. R. Jeffers
      (Merlewood)
      - Head of Subdivision of Data and Information
        C. Milner
        (Bangor)
      - Head of Subdivision of Chemistry and Instrumentation
        S. E. Allen
        (Merlewood)
      - *SPSO Special Merit*
        - Biometrics Research
          J. G. Skellam

Figure 2 ITE divisional and subdivisional staff structure.

resources needed, and a provision for periodic review of how the work is going.

Most new projects will arise from the ideas of members of staff in the middle levels – at Principal, Senior and Higher Scientific Officer grades – or, of course, from the needs of customers. An officer seeking to undertake a new project, or asked to develop one for a customer, will first obtain professional guidance from the appropriate Head of Subdivision. He will then seek advice, as appropriate, from statistical advisers about the design and analysis of experiments and survey; from the Chemistry and Instrumentation Subdivision about demands for analytical and technical services; and from the Station Secretary about the need for local resources at the laboratory concerned. The Station Secretary will also help to cost the proposal. The resulting project plan, after agreement by those centrally involved, will go forward for Management Group (and, where appropriate, customer) approval, and, after endorsement, its implementation will be the direct responsibility of the Project Leader. In the Project Plan, the participation of supporting staff will be carefully spelt out, and junior staff may also help to plan and implement, on their own account, sub-projects which will provide training, as well as contributing to the whole project.

Directorate and strategy: the management group

The Director of the Institute is responsible for the main balance of research commitments, and for ensuring that the Institute as a whole runs smoothly and efficiently. He is especially concerned with its strategy and place in the national context, and undertakes a good deal of liaison with Government departments and other 'customers'. The Deputy Director is responsible for much of the basic management of the Institute, and especially for ensuring that commissioned work is promptly and efficiently carried out in accordance with contractual agreements. He also heads one of the three main professional Divisions – the Division of Scientific Services – and has direct personal responsibility for the Institute's management information system.

The Director and Deputy Director, with the two other professional Heads of Division and the Institute Secretary, form the Management Group which is the central policy-making body (see Figure 1). It meets monthly, visiting the Institute's laboratories in rotation. The Group examines and approves all project plans, agrees the leadership and composition of all project groups, agrees policy, and debates objectives and general policy themes. On the other hand, it does not interpose itself between Division and Subdivision Heads and their staff or take on executive duties proper to individual officers.

The professional axis: divisions and subdivisions

There are three professional Divisions in ITE: the Division of Plant Ecology, the Division of Animal Ecology and the Division of Scientific Services. All are lead by scientists at Deputy Chief Scientific Officer level (see Figure 2). The Deputy Director, Mr J. N. R. Jeffers, heads the Division of Scientific Services; Professor F. T. Last heads the Division of Plant Ecology; and Dr J. P. Dempster heads the Division of Animal Ecology.

The Heads of Divisions are supported by Subdivision Heads. Within the Division of Animal Ecology, there are three of these concerned respectively with Vertebrate Ecology, Invertebrate Ecology and Animal Function. The first two of these Subdivisions cover the distribution, abundance and behaviour of vertebrate and invertebrate animals respectively, and their relationship to environmental factors. The third Subdivision is concerned with the basic physiological, biochemical and genetic processes of animals, and the impact of toxic substances and pollutants upon these processes. There are also three Subdivisions within the Division of Plant Ecology. The first, the Subdivision of Plant Biology, deals with the physiology, genetics and microbiology of plants and their roles as determinants of distribution and behaviour in the field. The second Subdivision, concerned with Plant Community Ecology, brings together staff studying the dynamics, distribution and description of plant communities and their environments and the effects of land use and management upon them. The third, the Subdivision of Soil Science, groups staff working on the whole spectrum from the description of soils and their formation through to the activities of micro-organisms, plants and animals within soils, and their vital role in the re-cycling of nutrients.

The Division of Scientific Services has two Subdivisions, one being concerned with Data and Information and the other with Chemistry and Instrumentation. The former is concerned with the application of biometrics, statistics, systems analysis, computing and recording to ecological science. The second provides chemical and instrumentation services throughout the Institute.

Some projects will be self-contained. In other circumstances, a series of projects involving people with different expertise will form an assemblage of projects and people, and a Project Group Leader will be designated by the Management Group, with responsibility for overall co-ordination. Sometimes several NERC Institutes may be involved, in which case a central co-ordinating role may be undertaken by NERC HQ. A Project Group Plan will indicate how the various components fit together, and how the co-ordination of the separate projects will be achieved.

Some Project Groups will be set up for short-term extensive programmes like the surveys the Institute has recently carried out in Shetland to assess the ecological impact of the proposed developments. Others may be virtually permanent features of the Institute's organization and comparable with the sections into which the research staff of the former Nature Conservancy were grouped.

The administrative axis

The Institute Secretary is the professional head of all administrative and executive staff, and carries responsibilities for matters of establishment and finance, estimating, accounting, and the co-ordination of administrative support. He looks to, and maintains liaison with, NERC HQ, for such procedures must be uniform throughout the Council, and indeed more widely in the public service. Under him, the Station Secretaries manage the business of the various laboratories, handling local financial and administrative matters such as the preparation of station estimates, ordering of supplies and equipment, payment of local wages and expenses, and help project leaders in costing project plans. Some staff are recruited locally by the Station Secretaries. Station facilities and vehicles have to be managed and maintained locally. In all this, the Station Secretaries provide support, freeing the scientific staff to concentrate on research.

Senior officers of Stations

There are some local tasks which a Station Secretary cannot perform, and which inevitably fall to the most senior officer of a Station. Some are representational, like receiving distinguished visitors, presiding at Open Days, or liaison with the Local Authorities on behalf of ITE. Others are more personal, such as helping staff in personal difficulty or needing advice, and resolving relationship problems within the Station. These duties were delegated to Station Directors in the former Nature Conservancy when the Stations were semi-autonomous units, and they remain an important task of Senior Officers, although Station Secretaries have been delegated substantial supporting duties, and, at the larger stations, other members of staff will support the Senior Officer by carrying responsibility for assigned areas of activity.

Headquarters

The Institute of Terrestrial Ecology is unusual in having a very small headquarters (only fourteen people), and a dispersed directorate. Of the more senior officers, only the Director and Institute Secretary are based at the Headquarters in Cambridge. The Deputy Director is stationed at Merlewood Research Station in Cumbria; the Head of Division of Plant Ecology at the Bush laboratory near Edinburgh; and the Head of the Division of Animal Ecology at Monks Wood near Huntingdon. Subdivision Heads are also widely dispersed, it being the aim of management to have an officer with this level of seniority at most of the stations.

There are dangers in such dispersion, unless communications are unusually good. There is a risk of the duplication of work – or contradictory initiatives by senior officers. An alternative danger is that vital tasks will be neglected because they fall between the areas of clear responsibility of different officers. Worst of all, dispersion could make it more difficult for the senior staff of the organization to function as an entity. The monthly system of Management Group meetings, in rotation at different stations, is designed to prevent such inefficiencies as well as to ensure that all staff have regular contact with senior officers. All senior officers, in addition, travel fairly extensively. But there are real advantages in the dispersion of senior staff. It avoids a dichotomy between the headquarters, centralizing all policy decisions, and research staff who may find themselves excluded from the discussion of issues in which they could play a valuable part, simply through remoteness, and because it is a fact of human nature that most people habitually form decisions within a fairly small circle of contacts. In a dispersed directorate, there has to be consultation between widely-based people, many of whom are influenced in their thinking by the staff with whom they have day-to-day contact.

Advice

Under its charter, the Natural Environment Research Council has a duty both to promote understanding of the sciences of the natural environment and to provide advice based on this understanding. The Institute of Terrestrial Ecology, within NERC, shares these duties.

There is a difference, however, between the advice ITE can and should give and that to be looked for from the Nature Conservancy Council, whose statutory duties differ. This difference can be simply stated. ITE, like other components of NERC, is concerned with basic science and not with value judgement or the advocacy of particular policies. Our task is to state the ecological and environmental features of an area, explain the ecological characteristics of species, predict what will happen under various circumstances, and suggest (if so requested) how management may mitigate the impact of a development, or restore a damaged site. This advice should form a scientific foundation for land management policies, which other agencies will develop. As one of these agencies NCC has a particular duty for nature conservation and will evaluate sites and situations to this end, advocating courses of action that best protect the conservation interest.

Jobs in ITE

Over the years we receive many enquiries from people who want a career in ecology. We have to tell them that at present vacancies in ITE occur rarely, and that all are subject to considerable competition. But there are some general guidelines that prospective candidates may like to note.

No research organization can be better than the cumulative skills of its staff. The project register and the summaries of completed research give some indication of the breadth of expertise which is now contained within ITE although they do not necessarily reveal the kinds of people the Institute will seek to fill particular staff vacancies which may become available. It must be emphasized that, in today's world, no ecologist can expect to operate without at least a basic standard of numeracy as well as of literacy. If the scarce resources available for research are to be used properly, research projects need to be designed efficiently, and, before data are acquired, the problems of handling and interpreting these data must be anticipated and solved. It is not a satisfactory solution to have statisticians acting as consultants solving the problems of biologists who lack mathematical aptitude or inclination. ITE's policy is to seek numerate biologists who are capable of working closely with its professional statisticians, but who are themselves able to undertake most of the computational and statistical tasks which are necessary for their results to be evaluated meaningfully.

This trend towards increased mathematical ability, characteristic of ecology today, is parallelled by another need which, in contrast, may seem surprisingly old-fashioned. Unless it is possible to assign organisms encountered in the field with reasonable confidence to taxa that have been described and can be recognized again, many of the ecologist's activities may be wasted. Universities today are less and less geared to the training of biologists who have this basic taxonomic aptitude, or even that interest in natural history which is the first requirement of the practising ecologist. This lack of taxonomic competence is worrying, for it makes many of the graduates of university departments that have moved with this trend unemployable in a research institute like ITE. It is particularly unfortunate for students who have devoted several years of their lives to courses only to find that their training has not equipped them for the career in ecology to which they are drawn. In sum, to be an ecologist, one must first be a naturalist.

Evolution and review

There is nothing wildly revolutionary about the organization of ITE. Many Government research establishments are organized with a primary Divisional structure based on professional discipline, with multidisciplinary groups as the second axis of a matrix, and more ephemeral in nature as demands on the organization change. There is nothing new in basing a research planning and accounting system on project plans. The changes in the structure of ITE do mean a constrast for those staff who formerly worked in the Nature Conservancy, but, just as the organization was different then, so was the national situation and the national need. The most experimental aspect of ITE organization is its dispersed Directorate, and this will need to be judged as experience of its work grows. The next years will undoubtedly see an evolution in the structure and functions of the Institute; hopefully, the system now introduced will, however, prove viable in its main features and thereby give stability to staff who have had more than their fair share of uncertainty and upheaval over the past years.

The research of the Institute in 1973–1974

Introduction

There are over 400 current research projects in ITE. Most are in Britain, but it is Institute policy to undertake assignments abroad, especially in developing countries, if requested by the Government concerned or by international agencies. They are at all stages, from exploratory investigation to the completion of accounts for publication. In choosing material for this Report our first aim has been to have a story to tell. There is little point in the kind of entry that records that 'four hundred samples of oakwood litter fauna were collected this year: a similar number will be obtained next year and after the identification of the species present and analysis of the results, a full report will be published around 1980'. In the following pages, short summaries are given of some 78 projects that were near enough to completion in 1974 for the results to be apparent. The contributions have been arranged in a fashion that broadly follows the themes of the Subdivisions, but some span many disciplines and demonstrate the work of larger project groups – such as those concerned with the possible environmental impact of the Maplin airport project or of water storage reservoirs in the Wash. For those who need a full index of ITE research, the project register in Section IV allows the work described here to be viewed in the wider context of our total research effort.

Vertebrate ecology

The Institute's research on vertebrates has concentrated on population dynamics and the environmental factors that determine animal numbers; predator: prey relationships; and the interactions between herbivores (including deer, sheep and grouse) and the vegetation they browse or graze. In addition, there have been surveys and special studies for conservation purposes.

The following contributions illustrate the spread of this work. P. S. Maitland reports on a review of fish conservation in Britain. The investigations of shelduck by D. Jenkins and Red grouse by A. Watson (who heads a special team outside the Vertebrate Ecology Subdivision) are concerned with how numbers are adjusted to habitat. R. E. Stebbings predicts the likely effect of a major land use change in a tropical rain forest area on bats and swiftlets, and discusses how bat populations in Britain may respond to climate. R. K. Murton's, Head of the Subdivision of Animal Function, research on Eared doves in Argentina provides a good example of how 'pests' can be created by particular land use practices. The note by I. A. Nicholson and B. Mitchell conversely illustrates how difficult it can be to improve the growth rate and carcase size in a cropped deer species if a long period of overgrazing has depleted the range, while V. P. W. Lowe and A. S. Gardiner underline how important it is to look at the genetic constitution of a herbivore rather than take it for granted that all 'Red deer' are *Cervus elaphus!*

REVIEW OF FISH CONSERVATION IN THE BRITISH ISLES

Following the publication of the first complete set of maps showing the present distribution of freshwater fish in the British Isles, it was possible to review the status of each species and indicate where conservation measures appeared necessary. The total value of freshwater fish to the community is far greater than is normally appreciated. In addition to the economic, sporting and commercial fisheries, it includes aspects of amenity, recreation, educational and scientific use as well as a potentially valuable gene-bank for the future.

The main human pressures on existing fish stocks are due to the development of fisheries, pollution, and changes in land-use. The principal trends in the British Isles are away from natural and stable mixed-fish populations towards artificially maintained, unstable stocks of a few species with a sporting or commercial value. In particular the rarer, more sensitive fish stocks with limited distribution are being eradicated and replaced by commoner, more robust forms with a wider distribution. The rarer species and genetic strains can only survive if constructive conservation projects are promptly initiated at various levels, and the research described here will be available to the Nature Conservancy Council on whom responsibility for these measures rests.

P. S. Maitland

POPULATION CONTROL IN SHELDUCKS AT ABERLADY BAY, FIRTH OF FORTH

Aberlady Bay is an important wintering and breeding ground for adult shelduck. There has been little change in the numbers of birds there since 1967, and a study of the reasons for this stability has been carried out. A hypothesis accounting for the birds' population dynamics is described in *Journal of Animal Ecology*, Volume 44, 1975.

The main idea is that there is active regulation of the numbers of breeding and non-breeding residents, because bird numbers are adjusted to the food supply. Breeding birds are believed to feed in the richest areas, while other resident adults taking poorer foods failed to breed. Another idea is that there are local high-density and low-density shelduck populations in the Firth, and that the high-density populations do not produce enough young to maintain their numbers,

Plate 1 Cock Red Grouse (Lagopus lagopus scoticus) *on a heather moor in North East Scotland. Photograph N Picozzi.*

Plate 2 Niah Cave, Sarawak. Several hectares of cave wall and roof are covered with bats such as this small (8 g) Horseshoe Bat (Hipposideros galeritus). *About 500 000 bats were present in total. Photograph R. E. Stebbings.*

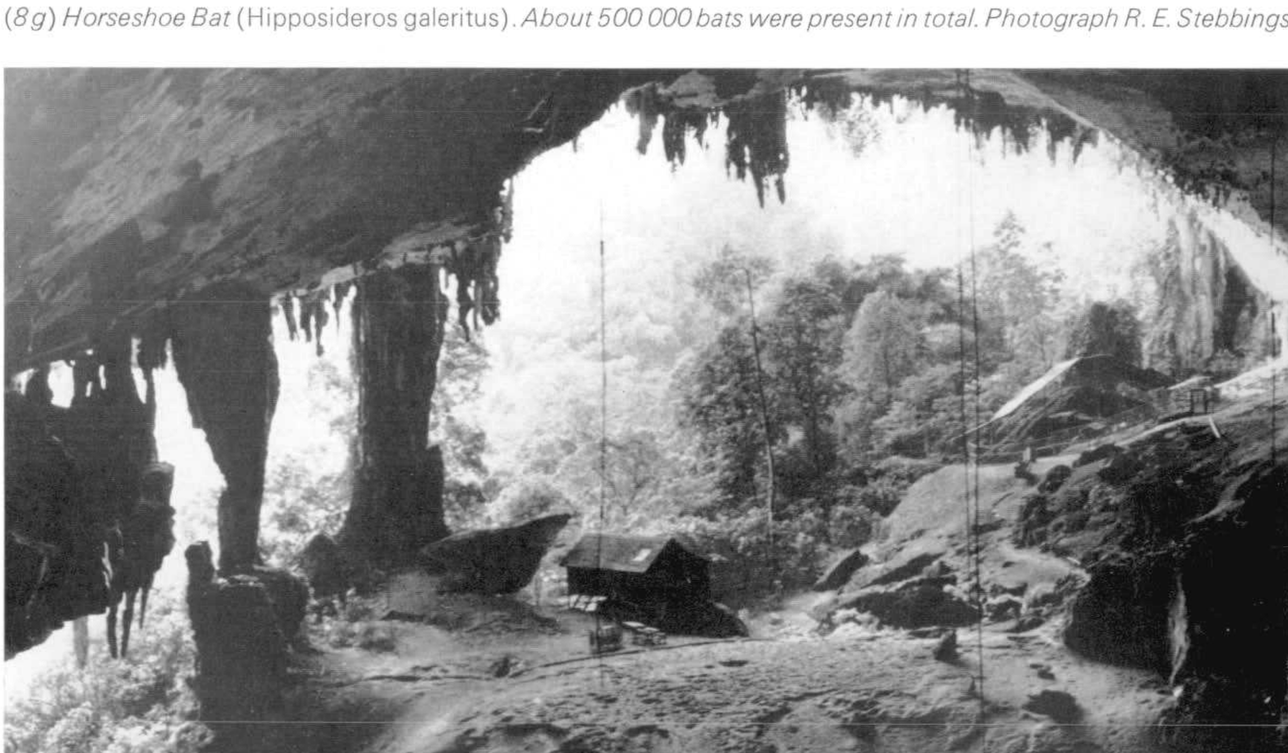

Plate 3 Niah Cave, Sarawak. The west entrance showing the hut where laboratory work was done. The hanging belian poles are used by the bird's nest harvesters and reach 80m and over in height. The ground is covered with guano. Photograph R. E. Stebbings.

obtaining recruits from low-density populations where the survival of young is better. Overall, the birds are long-lived and there is usually a surplus of young produced. The population of shelducks in the whole Firth of Forth thus functions as one unit with more birds than there are breeding places, with a considerable interchange of transient non-breeding birds between the component estuaries, and with mortality falling mainly on these birds.

At Aberlady, birds return from a moult migration to Germany round about New Year and similar numbers were found in the estuary during most of January and early February from 1967 to 1974. Occasional transient birds stayed a short while. From about mid-February on, the local population divided into two parts, with some birds present all the time and others seen only around high tide. Thus there were three kinds of birds altogether, occasional transients, resident commuters which disappeared around low tide, and permanent residents present all the time. The sediments in the Bay could also be divided into three main classes: biologically rich mud exposed at low tide, less rich silts near the head of the estuary, and biologically poor sand mostly near the sea (Figure 3). In winter, up to about mid-February, all three classes of birds feed on the mud and silt. As the birds' aggressiveness increased with the approach of the breeding season, the transients were first excluded from the whole Bay, and later the commuters were gradually excluded from the food-rich mud. From about March onwards, the permanent residents took up territories over the whole area of mud and silt, and from then on the commuters were only found on the sandy areas, or left the estuary altogether. The permanent residents with territories were the only birds to nest.

The dominance hierarchy underlying this division of the stock into three social classes, and the dispersion of, and interchange between, birds of different social status have not yet been fully documented. More work is also needed on the adjustment of bird numbers to

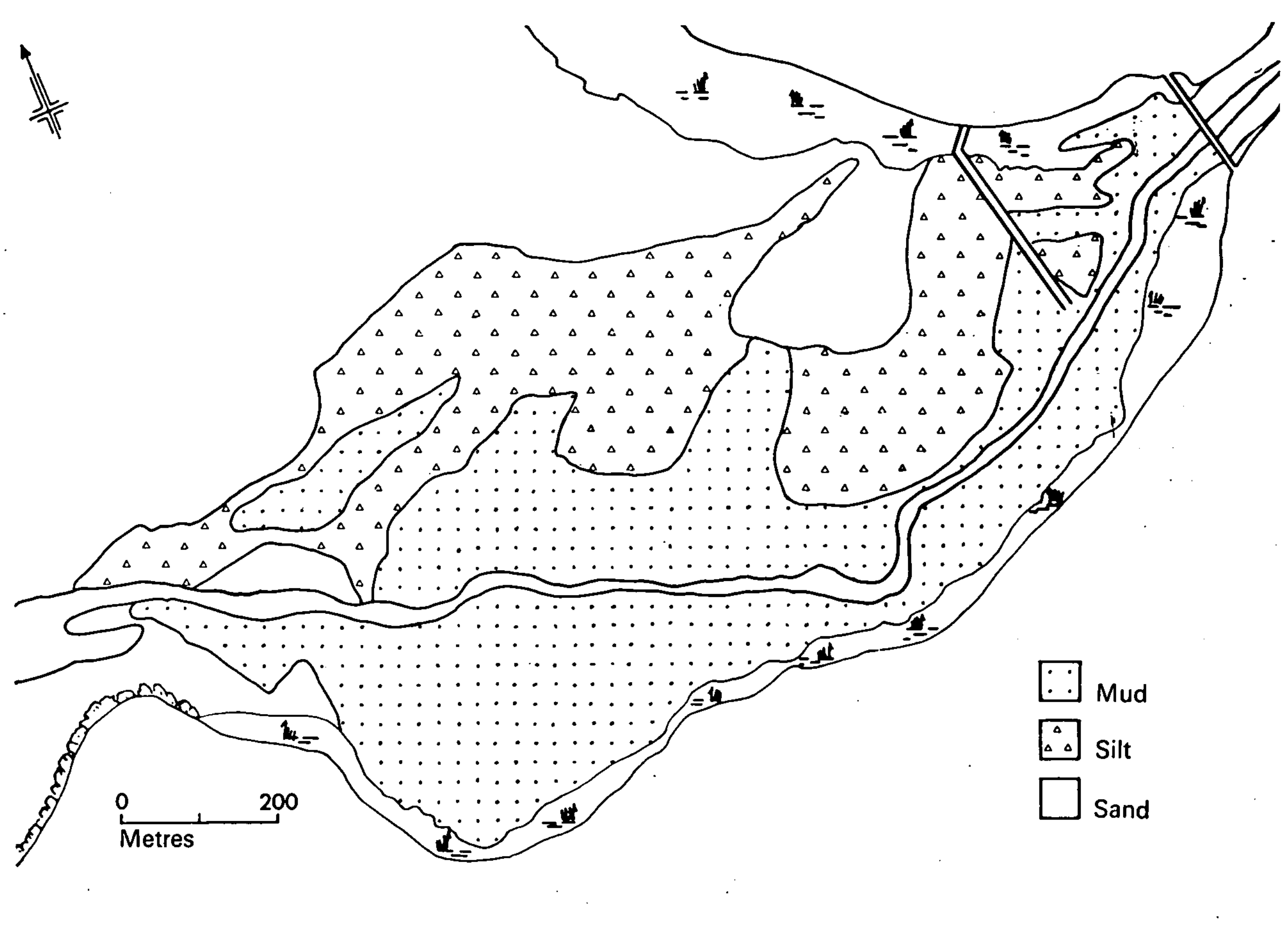

Figure 3 Study area, Aberlady Bay, Firth of Forth.

food, and on the causes of mortality. Research of this sort is highly relevant to the conservation of estuaries. Understanding how bird populations disperse in relation to their food, will enable ecologists to advise planners about the reclamation and development of estuaries.

D. Jenkins

GROUSE RESEARCH

Traditionally, ecologists who were studying vertebrate populations have interested themselves in the densities of the populations and in how variations in food and other resources affect these densities. Attention has been concentrated on mortality directly due to factors such as starvation and predation, rather than on the effect of changes in the behavioural type of the animals themselves. The research on Red grouse (see Plate 1) in north-east Scotland is one example where the social behaviour of the birds themselves has been found by experiment to be the immediate factor limiting the density of the breeding population in spring. Evidence is also accumulating with the Red grouse studies that small changes in their plane of nutrition can affect their behaviour and performance even though a vast excess of heather is available as potential food. One of the main conclusions from work done before 1970 was that population declines of Red grouse followed decreases in the quantity and quality of their spring food. The hens reared small broods, and a few of the young cocks from these broods succeeded in getting territories in the following autumn. The population density in the next spring was lower because a greater than usual proportion of an already smaller autumn population failed to get territories and died over the winter, and because the young cocks which were successful in getting territories took very large ones.

After a big increase of grouse from 1969 to 1971, their density at Kerloch, near Banchory, has been extremely high, reaching one territorial cock per hectare. This has coincided with a run of unusually mild winters and springs, when the heather has wintered well and grown early in the spring. The hens have continued to breed well. Nevertheless the population has now declined greatly, not because the cocks increased their territory size, but because half of them failed to pair up, even though many hens were available. Thus the number of young reared fell greatly even though the mean size of the broods did not. This unexpected decline is leading to studies to find out why so many hens fail to pair.

A. Watson

CAVE SWIFTLET AND BAT FEEDING RANGES, SARAWAK

A 5-week project was undertaken in northern Sarawak in 1974 on behalf of Hunting Technical Services, and financed by the Federal Government of Malaysia and Sarawak State. During the next few years substantial economic development will involve the felling of large tracts of tropical rain forest and the introduction of large areas of crop monoculture. The purpose of the project was to assess the effects these changes may have on the fauna of the renowned Niah Caves. About two million cave swiftlets of three species (some producing the nests that are used for birds-nest soup) live in the caves as well as about 500000 bats of seven species. The swiftlets leave the cave at dawn and often return after dark (navigating by echolocation), while the bats emerge at nightfall and return at dawn. Both bats and swiftlets feed on insects caught during flight. Although a few sq km will remain as a protected forest reserve, agricultural areas will be created only 3–5 km from the caves. Swiftlets were found feeding at distances up to 42 km from the cave (implying dispersion over 3500 sq km), and from indirect evidence it was likely that bats would feed over a similar area. (See Figure 4 and Plates 2 & 3.)

Samples of bats and swiftlets were collected and brought back to England for pesticide analysis, to provide a base-line for future work. The analyses showed that while four species did not carry any detectable organochlorine pesticide, four bat and two bird species contained measurable quantities of *pp'*-DDE. One bat carried a near-lethal load of the chemical. Several years spraying of pools with DDT to combat malaria was the probable source of this contamination. Apart from direct poisoning by pesticides, the major threat to the aerial fauna of the cave and the dependent cave invertebrates is the change in insect diversity and probable reduction in insect densities associated with loss of rain forest.

R. E. Stebbings

POPULATION ECOLOGY OF LONG-EARED BATS (*PLECOTUS*)

Two morphologically similar species of bats (*P. auritus* and *P. austriacus*) occupy roosts within the ITE Research Station at Furzebrook, and they have been studied since 1960. *P. auritus* is common and widespread throughout Britain, while *P. austriacus* is probably limited to a few sites along the south coast of England. The Furzebrook colony of *P. austriacus* is the only one known in Britain.

In 1961–62 *P. austriacus* numbered about thirty-two but *P. auritus* only numbered about twenty bats. As a result of the very cold 1962/63 winter the *P. austriacus* population crashed leaving only four

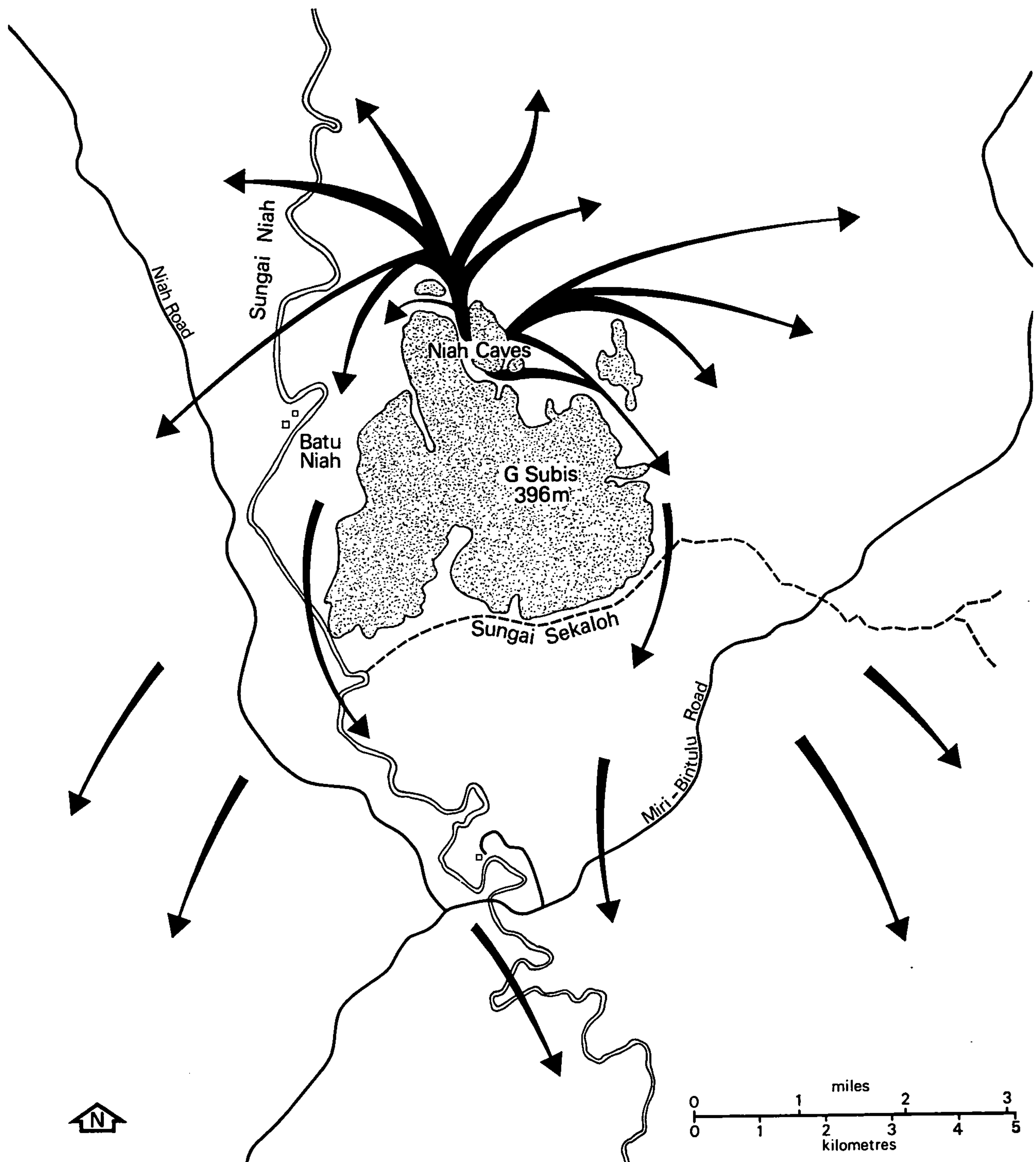

Figure 4 Swiftlet feeding range, Niah Caves, Sarawak. Daily emergence and return flight paths were constant. Swiftlets did not fly over the limestone massif (shaded) which rises steeply over 300m above the coastal plain. Birds often fly higher than the outcrop but never over it.

survivors while *P. auritus* remained unchanged. From 1963 to 1970 there were small and gradual changes in the numbers of both species but the combined populations remained remarkably constant for eight years. The mean annual variation in population was less than one bat. It appeared possible that these two species were competing either for optimal roosts or for food. Measurements of various roost parameters indicated that *P. auritus* was using the more favourable sites, which potentially would lead to higher birth rate and higher juvenile survival.

The size and morphological variability of *P. auritus* was examined throughout Britain. Variability and size were found to increase with increasing latitude. From concurrent but more detailed studies on *Pipistrellus*, this could be partly explained by an increase in body size as temperatures fell, but increased variation in some character measurements suggests the niche occupied in the south of England expands northwards to include similar niches that are vacant since there are fewer species. Small morphological changes that occurred at Furzebrook before and after the population crash of *P. austriacus* also indicated a niche expansion for *P. auritus* during the late 1960's.

R. E. Stebbings

THE ECOLOGY AND ECONOMIC STATUS OF THE EARED DOVE IN ARGENTINA

The Eared dove (*Zenaida auriculata*) (see Plate 4) is widespread in South America, where it is primarily adapted to live in arid and semi-arid scrub-land. Such an ecotone is provided by the chaco region of Argentina and Paraguay, a dry inhospitable country of low fertility and dusty soil surrounding the rich alluvial pampa. Cattle rearing is the ideal form of agricultural development in the chaco, but requires a high capital outlay. Consequently arable farming is preferred for its cheaper initial costs, despite the risk of creating dust-bowl conditions. The present mosaic of scrub, and such field crops as sorghum, provides ideal feeding conditions for any species adapted to exploit local patches of good food supplies, and the Eared dove has increased to pest status. Many roosting or breeding aggregations of around one million birds occur and from these centres large flocks can rapidly locate and deplete a ripening crop.

During a visit in March–April 1974 the problem was examined and a continuing programme of collaborative research designed with Dr E. Bucher of the Centro de Zoologia Aplicada, University of Cordoba. Already, some of the ecological conditions favouring gregarious behaviour in this species have been measured, related to agricultural damage and contrasted with the type of land use in the fertile pampa. Here the species is territorial and relatively evenly dispersed and the absence of enormous social concentrations means that intensive damage is not confined to relatively few unfortunate farmers.

The status of this dove provides an excellent illustration of how cropping patterns can create conditions which favour a particular pest and how in the long term sensible land management can solve the problem. *Zenaida auriculata* is also an ideal species in which to study the relationship between social organization and resource distribution and to construct predictive models.

R. K. Murton

ECOLOGICAL AND MANAGEMENT STUDIES ON A SCOTTISH HIGHLAND DEER FOREST

An opportunity to study a typical Scottish deer forest arose in 1966 when the Nature Conservancy was offered research facilities at Glen Feshie, and invited to participate in management. This estate of 16600 ha in the western Cairngorms supports a Red deer population of about 2200 in winter and 2800 in summer. In addition to various ecological studies on the deer and their range, other investigations were undertaken to provide information directly relevant to management.

Glen Feshie extends from 300 to 1200 m in altitude, and just over one-third of the total area is below the tree-line. Less than 10% of this woodland zone now carries natural woodland, and these remnants will disappear if the present grazing pressure is maintained. The overall population density of Red deer (*c.* 130 deer/1000 ha, in winter) is very high, but this gives little indication of the extremely high concentrations (around 1500 deer/1000 ha) found in parts of the woodland zone during winter. The adult deer are comparatively small, growth is slow, maturation is late, and reproductive success is low. These characteristics are undoubtedly related to the poor nutritional status of the habitat and to the long term effects of heavy grazing. Although a substantial reduction of deer numbers is the most important prerequisite for improving the performance of the animals and the potential of their habitat, any changes in either the animals or their range would be slow. Long-term heavy grazing has produced vegetation which is relatively unresponsive to short-term changes in grazing pressure.

If significant improvements are demanded within the period of a few years in which land managers today like to see their policies take effect, a substantial and relatively costly management programme would be needed.

A. I. Nicholson B. Mitchell

HYBRIDIZATION BETWEEN RED AND SIKA DEER IN NORTH-WEST ENGLAND

Suspected hybridization between Red deer (*Cervus elaphus* L.) and Sika deer (*C. nippon* Temminck) has been investigated since 1970, in the south-eastern parts of the Lake District.

Skulls of deer thought to be hybrids and of normal individuals of both species were measured and the data submitted to multivariate methods of analysis in an attempt to determine how far local Red deer stocks showed Sika characteristics. Most of the deer examined betrayed their hybrid origins through possession of external characters of both species, but others which appeared to be pure Red deer were also shot later so that the sample might include a complete range of types present in the district. On analysis all were found to be hybrids. Moreover, the external appearance of these deer was not always a good guide to their affinities. For instance, one stag appeared to be a Red deer with no Sika deer characteristics and another, a Sika deer with no Red deer characteristics. On analysis, the skull of the 'Red deer' was found to be more closely related to the sample of Japanese Sika deer than any other hybrid, and the skull of the 'Sika deer' occupied a position approximately midway between the species.

From our own observations and those in the literature, it would seem that hybridization occurs naturally only between Sika deer and Red deer of park origin (elsewhere, the two species appear able to co-exist without hybridization, as in Killarny in S.W. Ireland). However, when the progeny of such a cross are introduced into an area occupied by wild Red deer, introgression can occur naturally and unobtrusively, and cannot be eradicated or stopped once begun. In the Lake District, this will now result in the gradual reduction and ultimate loss of the last remaining native Red deer in England, the entire population being replaced by hybrids like those in the Wicklow mountains of Ireland.

V. P. W. Lowe   A. S. Gardiner

Invertebrate ecology

There have been three main reasons for the research done hitherto in ITE on invertebrate species: the need to define the invertebrate fauna of sites important to conservation and establish how this will respond to management; the need to understand the population dynamics of species important as determinants of ecological processes or (often because of rarity) as the subject of special conservation effort; and recognition of the important role of invertebrates in decomposer cycles.

The following notes illustrate the first two aspects of this work (the third being covered later in the context of Soil Science). R. C. Welch summarizes surveys of sites for the Nature Conservancy Council, and P. Merrett discusses the sampling of an important invertebrate group – spiders – and the methods used in different circumstances. M. G. Morris and E. A. G. Duffey outline how the fauna of chalk grassland and grass litter respond to grazing and trampling. M. D. Hooper and G. J. Moller (members of the Subdivision of Plant Community Ecology) examine how far two species of beetle moved between an isolated woodland and adjacent fields and hedges. M. V. Brian documents how fires which are common on dry southern heaths affect ant populations and G. W. Elmes discusses the role of different castes in these ants. The population dynamics of a common moth sometimes used to control ragwort have been analysed by J. P. Dempster, and its limitations as a control agent explained. E. Pollard and J. A. Thomas have similarly explored the population dynamics of two rarer invertebrates, the Roman snail and Brown hairstreak butterfly, and provided information that should aid their conservation and management. N. R. C. Webb has been studying populations of the soil mite (*Steganacarus magnus*), which is associated with decaying wood. He has worked out the details of its life-cycle which are shown diagrammatically. The late G. R. Gradwell and J. F. Benson studied the population dynamics of Scolytid beetles, which are vectors of the fungus *Ceratocystis ulmi*, the cause of Dutch elm disease.

INVERTEBRATE SURVEYS

Information about various invertebrate groups is often required by wild-life conservation organizations. Sometimes it is required to provide the main basis for selecting reserves and Sites of Special Scientific Interest (SSSI). More often it extends existing information about other wildlife, and ensures that conservation management takes account of rare insects and other invertebrates. Specialists in invertebrate groups willing and able to carry out the necessary surveys are usually few and far between, but ITE staff have been able to contribute in a number of ways. The surveys described below illustrate the help that has been given to the Nature Conservancy Council.

Galloway SSSI's. Several of the thirteen coastal and woodland sites surveyed were threatened with a change of management, and information on the fauna was urgently required to support the botanical data. This whole coastline is of considerable interest having a number of 'southern element' species. The fauna is rich: 748 species of Coleoptera alone were recorded. Several species were recorded for the first time in Scotland, including the snail *Vertigo angustior*; the littoral woodlouse *Armadillium album*; the bush cricket *Pholidoptera griseoaptera*; three beetles, including *Dirhagus pygmaeus*, and the spider *Entelecara acuminata*.

Bedford Purlieus SSSI. This site covers 210ha of mixed woodland, forming an outlying eastern fragment of the once extensive Rockingham Forest. It has an outstandingly rich flora, and supplementary information about the fauna was urgently needed to help in formulating the future management policy with the owners, the Forestry Commission. (The results of these studies are to be published as Volume 7 in the Monks Wood Symposium series.) Four hundred and seventy-three species of Coleoptera were recorded including *Gyrophaena williamsi*, found in the fungus *Tricholomopsis platyphylla*, and only found on three other occasions in England. Prior to 1961 thirty-nine species of butterfly were known from Bedford Purlieus. Ten have not been recorded since 1960, and another six have been lost more recently. These changes point to the need for careful management if the faunal diversity is to be sustained.

Staverton Park SSSI. A survey of this ancient medieval Suffolk monastic park in 1972 and 1973 recorded eight hundred and forty-six species. Several very rare Coleoptera including *Procaerus tibialis* and *Cypha pulicaris* (the latter the first English record) were found associated with the old oaks. A number of these beetles are only known from very few localities; mainly old forest areas and other parks. The spider *Pelecopsis radicola*, not uncommon in the park, has previously been recorded only twice in southern England. Very few such parks have been surveyed, and if we are to have a better understanding of the classic sites such as Windsor Forest or Moccas Park, many more will require survey so that their value as reservoirs for rare invertebrates can be assessed.

Cairngorms NNR. A survey was made of invertebrates from five sites on the Cairngorm–Ben Macdui plateau at an altitude of approximately 1160m which had suffered differing degrees of trampling or natural erosion. The results of this survey will be used to supplement botanical studies by ITE staff at Banchory.

R. C. Welch

A COMPARISON OF METHODS OF SAMPLING SPIDER POPULATIONS ON HEATHLAND

Ashdown Forest, Sussex, is 25sq km in extent, encompassing a valley between two gently sloping hills. About 70% of the area is heath, while the rest is mixed woodland. The variety of habitats and the spider fauna suggested its use in a general survey of spiders conducted over a wide range of lowland heaths in southern England.

Twelve heathland sites were chosen which showed considerable differences in height of vegetation, altitude 100 to 220m, proximity to trees, and amount of soil moisture. Each site had eight pitfall traps, from which spiders were sampled continuously for 1 year. The catch from pitfall traps is biased in favour of ground-living species, so it was decided to compare the results with samples obtained using a D-vac vacuum insect net. In the latter case two 1sqm samples were taken from each site on seven occasions between April and November. A total of one hundred and fifty-six species was recorded, one hundred and thirty-three in the pitfall traps and ninety-six in the suction net, the total number of adult individuals being six thousand seven hundred and fourteen in the traps and five thousand two hundred and ninety-two in the D-vac net. Table 1 gives the results for six species in detail. Taken in numerical order, the first four sites are wet, the next three are moderately wet and sheltered, while the remaining five are dry and exposed. The pitfall traps show best results for ground-living species, while the D-vac method is better for species higher in the vegetation.

A classification of sites based on spider catches, using Curtis' Index of similarity, gave groupings which correspond with that given above. This remained largely true whether the spider catches were taken as a combination of the two methods, or from each method separately. The highest number of species was taken by the D-vac in June, then October followed by May. If the July and September sampling had been omitted only one species would have been missed.

P. Merrett

THE BEETLE FAUNA OF GRAZED AND UNGRAZED GRASSLAND

Nearly 4000 different species of Coleoptera (beetles) occur in the British Isles and they are extremely diverse in their size, structure, behaviour and ecology. A study of the species inhabiting grazed and ungrazed chalk grassland on the Barton Hills, Bedfordshire, was started in 1966. In March 1965 sheep were excluded from two fenced areas each 40 × 25m, amid grassland that was otherwise intensively grazed. Samples from these exclosures and from two grazed areas of similar dimensions, were taken at 26-day intervals for 12 months in 1966–67 and again in 1972–73. The samples consisted of discs of turf cut from the plots and the beetles were extracted from them by heat

Table 1. Numbers and species of Spiders trapped according to sites

	Site 1 Isle of Thorns Wet	Site 2 Duddle-swell Wet	Site 3 Legsheath Wet	Site 4 Ridge Lower	Site 5 Twyford	Site 6 Ridge Upper	Site 7 Legsheath Dry	Site 8 Isle of Thorns Tall	Site 9 Gills Lap	Site 10 Kings Standing	Site 11 Duddle-swell Dry	Site 12 Isle of Thorns Sparse
A. proxima	134	30	13	21	48	23	2	51	96	167	180	108
	4	1	1	3								1
C. concinna	74	8		5	4	7		12	35	25	278	353
	1				2			2	2	2	3	11
P. gibbum	4	1	1		28	5	12	7	3	1	1	
	32	8	8	6	146	8	98	75	16	2	13	9
C. brevipes			1	5	5	80	7	184	18	23	18	64
				20	43	478	239	171	95	199	51	34
H. jacksoni	6	3	2	1	6					8	6	
	4	37	5	2	5				3	6	10	
S. gracilipes	18	6						4	10	5	21	11
	4										5	

For each species, upper figure refers to pitfall trap catch, lower figure to D-vac

treatment in special funnels. 4 sq m of turf were extracted during each 12-month period.

In 1966–67 the hills were grazed intensively, and the relatively small number of six hundred and fifty-four beetles were taken from the grazed plots. Seventy species were represented, including several associated with open conditions or with sheep dung. In the exclosures, with their taller vegetation, 1949 beetles were taken, of 106 species. These included feeders on specific plants as well as feeders on plant litter and predators.

Early in 1972 grazing had been much less intensive and no sheep were on the hills during the 1972–73 sampling period. On the grazed sites 1759 beetles, belonging to seventy-eight species were recorded, but fewer sheep-dung feeders were included. In the exclosures the number of species recorded fell to eighty although 2192 individual beetles were taken. Plant-feeding species were fewer than in 1966–67, but the number of decomposer species had increased and several, unrecorded in 1966–67, occurred in large numbers.

Pitfall traps set in 1966–67 showed that several large, active beetles which were not recorded in the turf samples occurred on the Barton Hills. The catches from the pitfall traps help to obtain a more comprehensive knowledge of the beetle fauna of the area.

It seems clear that the characteristic beetle fauna of grassland varies with the grazing regime of the present and immediate past.

The very short intensively-grazed turf has, particularly, 'open ground' species (mainly predators and foliage feeders) and beetles associated with dung. In the taller, floriferous ungrazed (but recently grazed) grassland the fauna is rich, with many plant-feeding species associated with flowers, fruits and buds. Denser, coarser grassland with few flowers and abundant litter contains many decomposer species. The implications of these facts for the management of grassland nature reserves seem clear. The different grassland types can be maintained by rotational management without necessarily having an adverse effect on the floristic richness of the turf.

M. G. Morris

THE EFFECTS OF HUMAN TRAMPLING ON THE FAUNA OF GRASSLAND LITTER

During the post-war years ecologists have become increasingly aware of the changes in wildlife communities brought about by the large numbers of people who now visit the countryside for recreation. Much information has recently become available on the effects of disturbance, such as treading on vegetation, particularly in semi-natural grassland, but virtually nothing was known about the effect on the invertebrate fauna. An experiment to investigate this was completed in 1974 at Monks Wood Experimental Station. The experimental area was a 7-year-old grass-ley where sterilized grass litter in nylon mesh bags was placed out in randomized plots. There were two levels of treading intensity: 5 treads and 10 treads per month respectively, and an untrampled control series. Twenty litter bags were taken up at 3-month intervals during the 12-month duration of the experiment, to measure the faunal changes taking place in relation to season and age of litter. As a result of natural decay the depth of litter in untrodden control bags fell from 8·9 cm to 4·2 cm, while with 5 treads/month it fell to 2·4 cm and with 10 treads/month to 1·7 cm. The dry weight loss in the control bags was 34% after 12 months and 94% in the 10 treads/month bags. Further evidence of structural changes was obtained by embedding and sectioning samples of treated and untreated litter in order to measure the proportion of air space by use of a Quantimet Image Analysing Computer. The respective measurements were 63·0% in the control bags, 54·0% in the 5 treads/month bags and 38·0% in the 10 treads/month bags.

The analysis of the fauna showed that most groups of invertebrates decline both in total numbers (50·3%) and in numbers of species (53·5%) in the trampled litter bags compared with the controls. However, changes in the number of earthworms and beetle larvae were not significant, and a small increase in Diptera larvae was recorded. Of the twenty-one most numerous Coleoptera species, seventeen declined sharply, two showed little change and two increased. The species of spiders, isopods, molluscs and millipedes were rather more sensitive to treading and none showed an increase. Only small non-significant differences (with the exception of the Araneae) were recorded between the faunas of the 5 treads/month litter bags and the 10 treads/month bags. Treading not only changed the structure of the litter but also forced earth into the samples forming a mud/litter matrix which appeared to favour certain species. Thus there is evidence that the invertebrate fauna of grassland litter is affected by levels of treading intensity much lower than those required to produce changes in the structure and species frequency of the living plants.

E. A. G. Duffey

BIOLOGY OF ISOLATED HABITATS

Studies on a number of herbs in isolated woodlands suggest that isolation in time is as important as isolation in space. When spatial separation is sufficient to prevent recolonization, it appears that extinction of species will occur at a rate correlated with the square of the number of species originally present. This implies that a wood, once isolated, will lose species rapidly at first but more slowly at a later stage, possibly because inter-specific competition has been reduced. It also implies that a species-poor wood could be regarded as more stable than a species-rich wood of equal size.

While this may be reasonable as a model for woodland herbs with very poor powers of dispersal, it seems unlikely to be satisfactory for organisms which might move along hedgerows thus reducing the spatial isolation.

Therefore in 1974, a pilot study was carried out on species of beetles in a small, isolated, broad-leaved wood. Pitfall-traps were set in hedgerows radiating from the wood, the arable fields adjoining the wood and the wood itself. The traps were attended daily over a 5-month period and a mark and recapture programme used.

Two species studied were *Abax parallelopipedus* (Pill. and Mitt.) and *Pterostichus melanaria* (Ill.), the former being essentially a woodland animal and the latter more widely distributed.

Although some specimens of *Abax* originally caught in the wood were subsequently found in the hedgerows and vice versa, there were insufficient data to conclude that there was any preferred dispersal pathway, as specimens were also trapped in the field site. *P. melanaria* moved freely between the three habitats with no preferred direction. For these two species the presence of hedges did not reduce the spatial isolation of the wood.

Individuals of *Abax* were found to travel considerable distances within the wood and there was considerable variation in numbers caught from day to day, even when the population was fairly stable.

This variation in activity seems to correlate significantly with nightly ground temperature (the animals are nocturnal in habit), but relative humidity also seems to affect *Abax*, as very high relative humidity (i.e. above 85%) reduced the catch drastically.

M. D. Hooper
G. J. Moller

THE EFFECTS OF THE FIRE CYCLE IN HEATHLAND ON ANT POPULATION

A fire ravaged part of Hartland National Nature Reserve in September 1959. The ground was exceptionally dry and the heat destroyed not only the aerial vegetation but much animal and plant life below the surface too. More important in the long term was the reduction of food available for invertebrate animals; in particular, the entire crop of heather seeds normally harvested and stored over winter by the continental Turf ant (*Tetramorium caespitum*) was lost. Since that time the changes in ant population have been followed by two methods. First, by recording the species present at 160 random sample sites over the 10 ha area that was burnt. Second, by marking and studying inten-

Plate 4 The Eared dove (Zenaida auriculata) *is a serious pest of sorghum and other grain crops in South America. Photographed coming to drink at a water hole in the Argentinian chaco. Photograph R. K. Murton.*

Plate 5 Pond 1. Control.

Plate 6 Pond 5. Twenty-six days after treatment with Diquat: 'algal bloom' clearly visible.

Plate 7 Pond 7. Fifty-two days after treatment with Dichobenil, July 1972.

Plate 8 Pond 6. Three years after treatment with Dichobenil, June 1974. Photographs C. Newbold.

sively twenty-eight colonies of the Turf ant; each year territory size, the number and size of workers and the number of sexual individuals produced have been measured.

The species survey has shown that between 1961, when vegetation was short and sparse, and 1971, when it was long and lank with a much stronger heather component, there was a big change in ant population. About one-tenth of the habitat was ant-free in 1961 but none in 1971 and on the latter occasion quite often as many as two species were found at a single bait point.

The commonest species in 1961, *Lasius alienus*, (an ant of open dry vegetation that lives by excavating nests and forages for soil insects in galleries just under the soil surface) has been reduced by half. This has been largely through expansion of the Turf ant but all species except the *Lasius* have increased their range.

The special study of colonies of the Turf ant has given more detail to the population picture; their territories increased, their individual size increased (but curiously not their colony size) and their production increased. Sexual production tended to rise slowly over the whole period but carried a biennial cycle too.

These observations combine to show that fire, apart from killing some ants directly, affects their food supply and their adaptation to the habitat. Soon after the fire a carnivorous species well known to live in sparse vegetation rises to a peak only to decline and be slowly replaced by several species better adapted to survive in tall rank bushes by virtue of better building skill and the ability to use plant produce, especially seeds, directly. Thus the ant species exist in an ecological balance tipped first one way by fire and then the other way by regeneration.

M. V. Brian

THE ROLE OF POLYGYNY AND MICROGYNY IN WILD ANT COLONIES

The Hymenoptera (ants, bees and wasps) very often live together in family groups. These societies usually consist of a queen, who lays the eggs, and workers who attend the queen and her eggs; males play no active role in the society and live just long enough to fertilize the female. In primitive social insect societies a fertilized female becomes a queen and an unfertilized female becomes a worker. Such workers can assume the role of a queen if they are subsequently fertilized. In the more advanced species the differences between the queen and worker castes have become quite distinct, and the workers have lost the ability to become queens. The evolution of a non-reproductive caste is difficult to understand, but recently it has been explained by a form of natural selection called 'kin selection'. In some species, particularly amongst the ants, more than one functional queen can be present in a colony. This is called polygyny. The queens of highly polygynous societies need not be much larger than their workers because they share the task of egg-laying and colony founding. This leads to a retrogression of the caste differences and often microgynes (miniature queens) are produced.

The social structure and population stability of polygynous species is being studied at Furzebrook. The genus *Myrmica* (common Red ants) provides species that show all types of social structure and is therefore ideal for study. So far results using mathematical models show that in a polygynous society the queens' relationship to workers is analogous to that of parasites acting on their hosts. Predictions made with the model have been verified by the observation of wild colonies. It has been suggested recently that social parasites are derived from polygynous species, and it is likely that many of the ants that are parasitic on *Myrmica* are derived from microgyne forms. A new form of *Myrmica sabuleti* that is half way between a normal microgyne and a parasitic form has also been discovered.

G. W. Elmes.

POPULATION STUDIES ON THE CINNABAR MOTH

A detailed study of the Cinnabar moth (*Tyria jacobaea* L.) and of its food plant (ragwort, *Senecio jacobaea* L.) was started at Weeting Heath in Norfolk in 1966. Since then the numbers of all stages in the moth's life cycle have been counted and the principal causes of mortality have been identified. From these data life tables have been constructed covering nine generations of the moth.

Weeting Heath is an area of sandy heathland which is heavily overgrazed by rabbits. Ragwort is extremely abundant, and varied from 8 to 68 plants/sq m during the course of the study. The moth's population has also fluctuated violently in size (Figure 5) and periodically it has completely defoliated its food plant over large areas. When this happens, large numbers of caterpillars die of starvation, and the adults which are produced are small in size and lay few eggs in the following generation. Adult fecundity is therefore dependent on the extent of larval crowding and so acts as a delayed density-dependent factor.

Mortality in the egg stage is low, but many newly hatched larvae are taken by spiders, mites and ground beetles. The caterpillars are distasteful to vertebrate

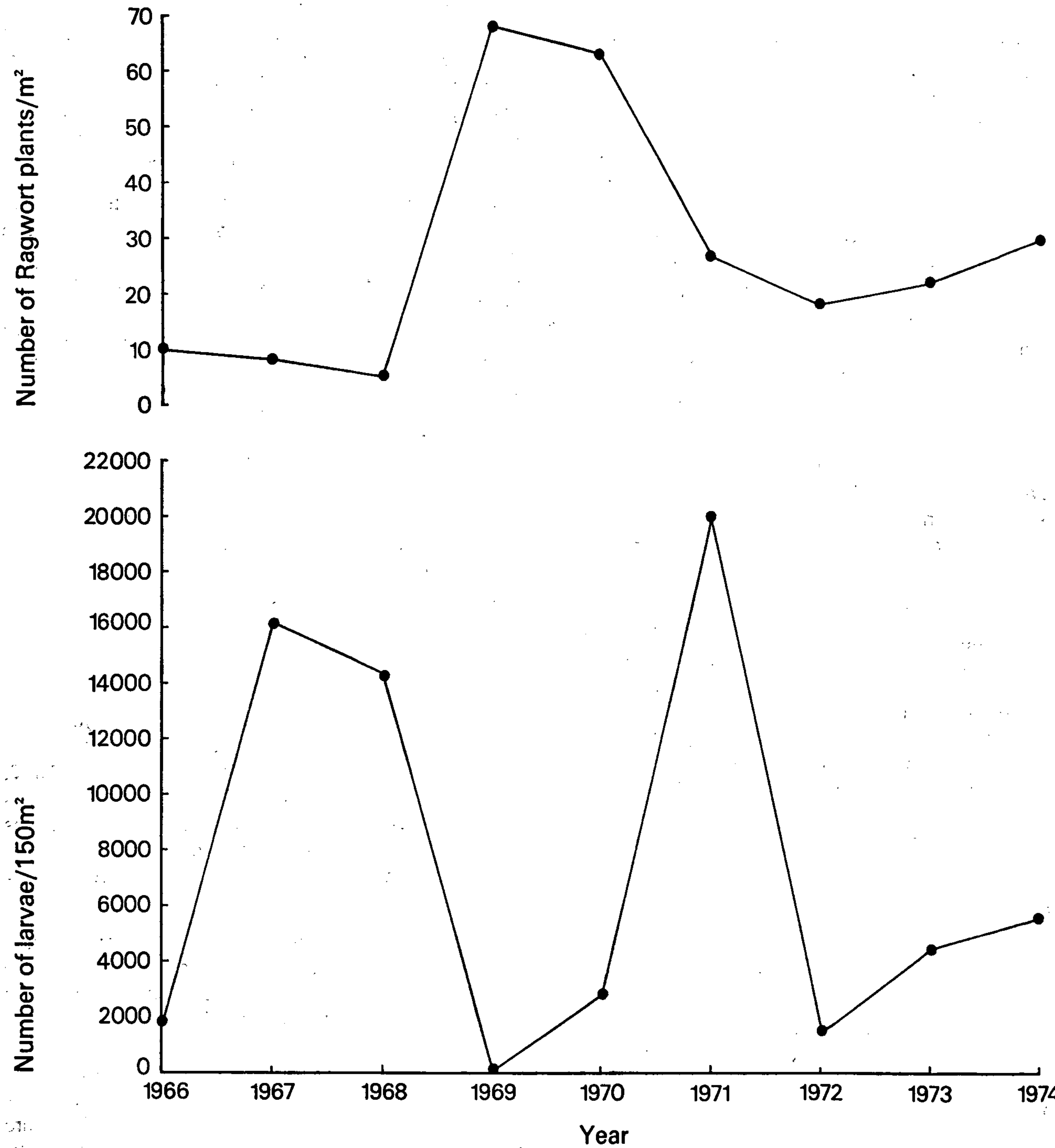

Figure 5 Population changes of the Cinnabar moth.

predators. A larval parasite, *Apanteles popularis* Hal. (Braconidae), kills up to 25% of the fully grown caterpillars in some years. The impact of starvation makes larval mortality density-dependent at densities of greater than 1000 larvae/kg ragwort. Mortality is high at, or immediately after, pupation, due to predation by moles (*Talpa europaea* L.).

Analysis of the life tables shows that larval starvation is the key factor determining the trend in population size. Upward growth of the population is limited by food supply, but the only factor which appears to buffer the population against extinction is the heterogeneity within the moth and plant populations. The earliest caterpillars manage to obtain sufficient food from those patches of ragwort which survive longest.

Ragwort is normally a biennial, but if damaged and prevented from flowering it can become a perennial. The plant can withstand defoliation well, and has enormous powers of regeneration either by producing secondary flowering shoots from the crown, or by regeneration from root buds. On the poor soil at Weeting this second type of regeneration is commonest. In wet summers the number of ragwort plants may be greatly increased by regeneration following defoliation. The rate of recovery by the moth following population crashes which result from starvation, depends largely upon the summer rainfall and the amount of regeneration by the plants.

Attempts have been made in many parts of the world to control the ragwort numbers by means of the Cinnabar moth. This study shows that three interacting factors determine the impact that the moth has on the plant, namely climate, soil and the extent of grazing. The moth can build up in numbers to a level where it defoliates its food plant only on well drained soils, since pupal survival is low if the ground becomes waterlogged. Mortality of the young caterpillars also tends to be higher in the lush vegetation found on heavier soils, and under less grazing pressure. In areas where the moth is capable of defoliating ragwort, its impact depends upon the powers of regeneration of the plant. This is affected by soil-type and climate, but above all, it is dependent upon grazing pressure. Ragwort seedlings and small rosette plants produced from root buds do not compete well with grasses if grazing pressure is low.

J. P. Dempster

ECOLOGY OF THE ROMAN SNAIL

A detailed study of the ecology of the Roman or Edible snail (*Helix pomatia* L.) has been completed. Individuals are long-lived, frequently reaching seven or more years (including the juvenile stages); thus the study of population change depends on long-term work.

The Roman snail occurs mainly on south-facing slopes with chalk or limestone soils in southern England. Intensive studies of a single population show that activity, mating, and egg-laying are dependent on rainfall. The adult snails show a regular seasonal pattern of movement over a distance of 15–20m away from and later back to hibernation areas. Individual snails seem to explore similar areas from year to year. The aggregation for hibernation ensures that partners are available for mating in the early spring before the main dispersal in search of sites for egg-laying.

An important advance in terms of the population studies has been the development of a method for classifying adults into growth classes, which are thought

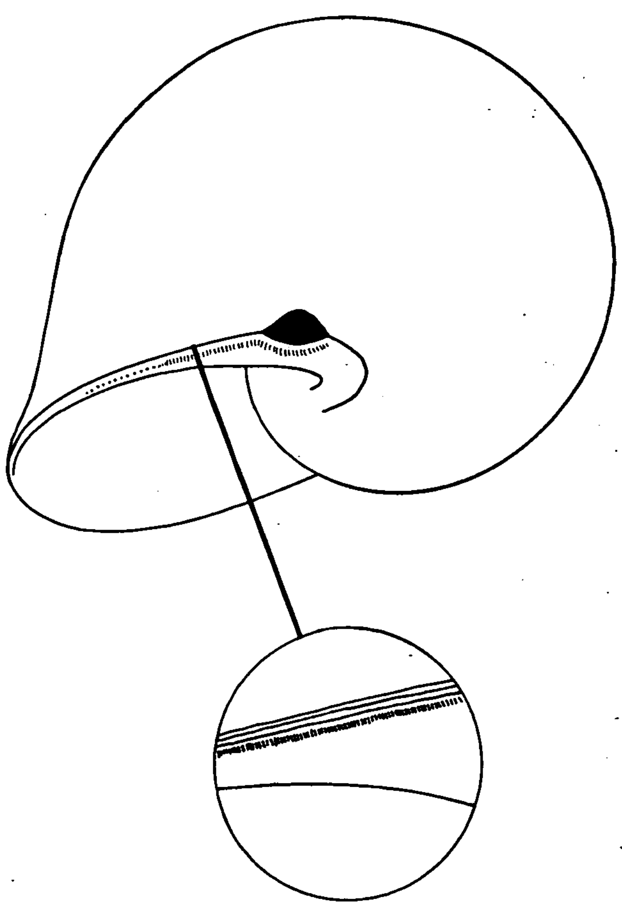

Figure 6 The external shell walls thicken with age in adult H. pomatia, *including the lip which shows laminations or growth rings.*

likely to be annual age classes. This is based on counts of rings formed in the lip of the shell as the shell thickens with age (Figure 6).

Many central and eastern European countries have large export trades in *Helix pomatia* and there has been severe over-collecting in many areas. It is hoped that the information from these studies will help in the conservation of the species both in England and abroad.

E. Pollard

THE ECOLOGY OF THE BROWN HAIRSTREAK BUTTERFLY

The Brown hairstreak (*Thecla betulae* L.) (see Plates 9 and 10) is a scarce and local British butterfly although its larval food plant, blackthorn (*Prunus spinosa*), is widespread and common. Research has mainly been concerned with its distribution and status, behaviour, population dynamics, and habitat requirements.

The distribution and status of this species has been studied in cooperation with the Biological Records Centre of ITE. It has been recorded widely but very locally, throughout southern Britain, and has declined in many areas in the past century. There are records of ninety-five colonies since 1960. Most occur on clay soils, especially on the Wealden Clay of West Sussex and Surrey.

The Brown hairstreak has one generation a year, with adults emerging in late July or August. The early stages are distributed sparsely over wide areas on wood edges, scrub and especially hedgerows. Emerging adults aggregate on the woodland canopy, sometimes on a single tree, where they mate and feed. Females then disperse to oviposit on any *Prunus* species encountered. In Britain this is usually blackthorn; indeed no colony is known where more than 3% of eggs are laid on other shrub species. Most eggs are laid singly near ground level, usually on young

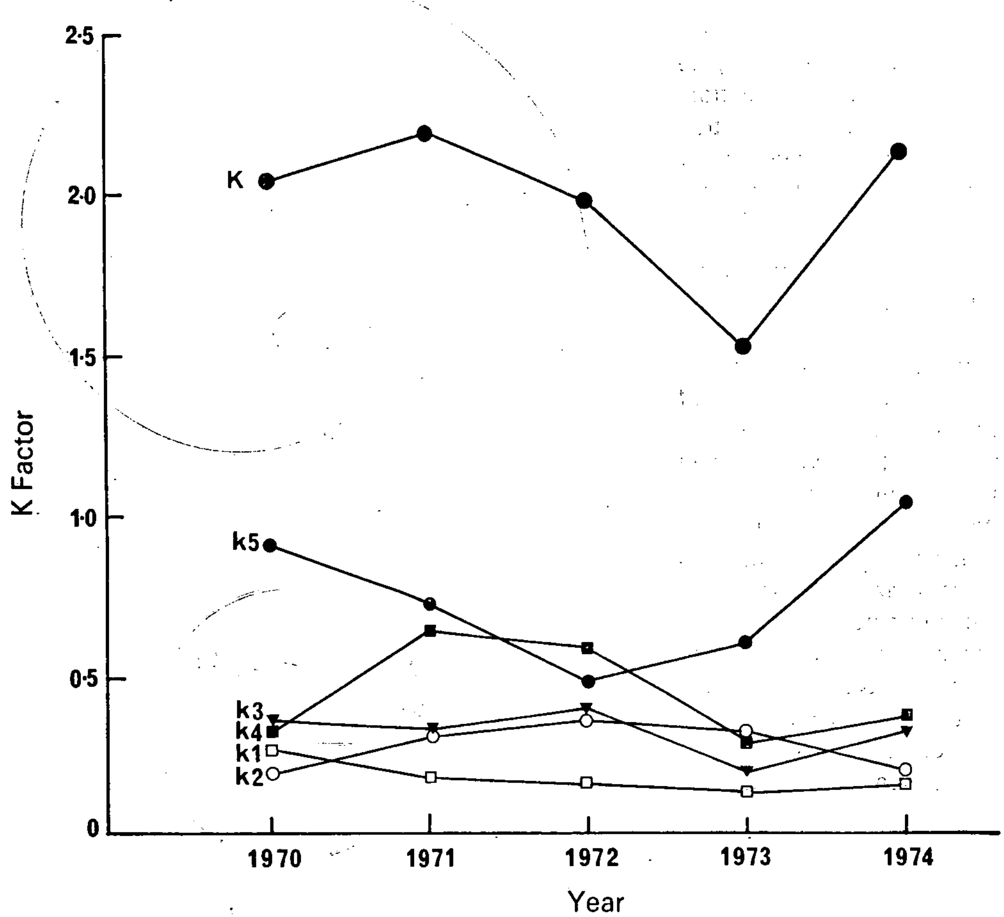

Figure 7 Key factor analysis of annual population changes in the egg stage of Thecla betulae *in Surrey.* (K = *log total generation mortality;* k_1 = *log egg mortality;* k_2 = *log larval mortality, instars 1 + 2;* k_3 = *log larval mortality, instars 3 + 4;* k_4 = *log pupal mortality;* k_5 = *log reduced fecundity.*)

plants. They hatch in late April and the larvae feed on *Prunus* spp. leaves, later pupating in leaf litter. The rate of larval and pupal development has been found to vary greatly with temperature.

The population ecology of a colony in Surrey has been studied since 1969. Eggs are laid over an area of 30 ha containing about 5750 *Prunus* spp. bushes along 16 km of hedges and wood edges. Annual estimates of egg numbers were obtained by searching about 10% of these bushes each winter, and estimates of the number of larvae, pupae, and adults were obtained by following the survival of between 200 and 600 of these eggs through to adults each year.

Between 1969 and 1974 egg numbers fluctuated between 1350 and 4160 producing an adult population that varied between 40 and 300 individuals. The population data have been analysed by the key factor method, by which the most important factors in changing population levels from year to year may be identified (Figure 7). In the first four years annual changes in the overall mortality suffered by all stages (K) were most influenced by changes in the severity of pupal mortality (k_4). This mortality is caused by predation by large beetles, such as Carabids, and small mammals. Reduced fecundity (the failure of females to lay their full potential of eggs, k_5) was also an important factor each year, and was so high in 1974 that it overrode the effect of pupal mortality, and caused a severe population decline. Fecundity is greatly influenced by the longevity of females and the weather. Females will not oviposit at temperatures below about 20°C and it is probable that the exceptionally cool and wet weather in August and September 1974 was responsible for the very low fecundity that year.

J. A. Thomas

THE LIFE-CYCLE OF *STEGANACARUS MAGNUS*

Steganacarus magnus is a common species of soil mite which lives in most types of leaf litter, where it is usually associated with decaying wood. It is a member of the group of mites called oribatid or beetle mites because they have a very thick exoskeleton. Populations of this species have been studied living in the heathland soils of south-east Dorset. In these soils the larval and three nymphal stages of the life-cycle are completed within the fallen cones of the Scots pine (*Pinus silvestris*). The juvenile mites eat the woody contents of the cone causing its destruction. By contrast the adult mites are to be found free-living in the litter. In other habitats the nymphs are to be found in other types of woody material. The details of the life-cycle, in the form that it takes in the populations under study, are indicated in Figure 8. *N. R. C. Webb*

POPULATION DYNAMICS OF SCOLYTID BEETLES, VECTORS OF *CERATOCYSTIS ULMI* THE CAUSE OF DUTCH ELM DISEASE

(Work carried out under contract placed with University of Oxford)

In the current outbreak of Dutch elm disease in southern England the elm bark beetles (*Scolytus scolytus* and *S. multistriatus*) are jeopardizing healthy trees by introducing spores of the prevalent virulent strain of the fungus *Ceratocystis ulmi* into wounds made when adult beetles feed on twigs. At first sight this ability to carry fungal propagules would appear to benefit only the fungus because the time taken by the fungus to kill the tree is sufficiently long to prevent the tree's use as a breeding site by the beetle or beetles which introduced the fungus. However, there may be benefits to the beetle about which, as yet, we know very little. The introduction of the fungus into the egg galleries by the adult beetles may make breeding sites more suitable for larval development. Alternatively the presence of the fungus in the egg and larval galleries may suppress the development of fungi pathogenic to larvae.

The usual 'text book' account of the beetle's life-history suggests that feeding on the thin bark of healthy twigs by newly emerged adults is essential for the maturation of their eggs. It is further suggested that it is only after such feeding that the females seek a suitable site in which to make their egg galleries. Newly acquired evidence suggests that the situation is more complex:

(a) Beetles emerging from 'large' logs kept in the laboratory immediately made feeding galleries (which were subsequently extended to form egg galleries) in other 'large' logs or in the one from which they emerged if it was still suitable. In these circumstances egg production appeared to be comparable to that of females which had fed on 'small' twigs.

(b) In the field, breeding attacks were found on elm logs before there was evidence of beetles feeding on healthy twigs in the vicinity of the logs.

(c) In an area without healthy elms to provide food, newly emerged adults were successfully breeding in logs placed close to emergence sites. If feeding on healthy twigs was obligatory these adults would have migrated.

Other observations indicate that beetles move relatively short distances after emergence if there is a plentiful supply of breeding and feeding material. In one instance signs of feeding on healthy trees and attacks on breeding material close to the sites of emergence lessened in frequency to virtually zero within a distance of 200 m.

This suggests that the main front of the disease may move relatively short distances, 100–500m per year, where elms are more or less continuously distributed and where there is not a shortage of suitable breeding material. However, it seems probable that beetles which have been unable to find breeding sites near to their sources of food will take flight and either fly or be carried by the wind over considerable distances. Beetles dispersed in this way may possibly reach healthy trees some distance from their emergence points, the transfer of *C. ulmi* and subsequent establishment of infection creating a new focus of Dutch elm disease.

The late *G. R. Gradwell*
J. F. Benson

Animal function

The research branch of the former Nature Conservancy made a number of important discoveries about the side-effects of pesticides on both individuals and populations of wild animals, especially birds. This work is being continued within the Institute of Terrestrial Ecology's Subdivision of Animal Function, mostly at Monks Wood Experimental Station, and the following reports summarize some recent findings.

The research has one inevitable component in the surveillance of the amounts of pollutant residues found in wildlife, and A. A. Bell reports on recent trends in dieldrin levels in birds of prey, while J. L. F. Parslow and D. J. Jefferies show how the amount of several pollutants in guillemots varies geographically, and pin-points the Irish Sea as the most contaminated 'hot-spot' among British inshore waters. However, the mere presence of such residues is unimportant unless they have effects, and a major aim of ITE research is to find out just what effect a particular level of exposure to a pollutant has on a particular species. Jefferies and Parslow show that in guillemots, polychlorinated biphenyls (PCBs) affect the thyroid; A. S. Cooke

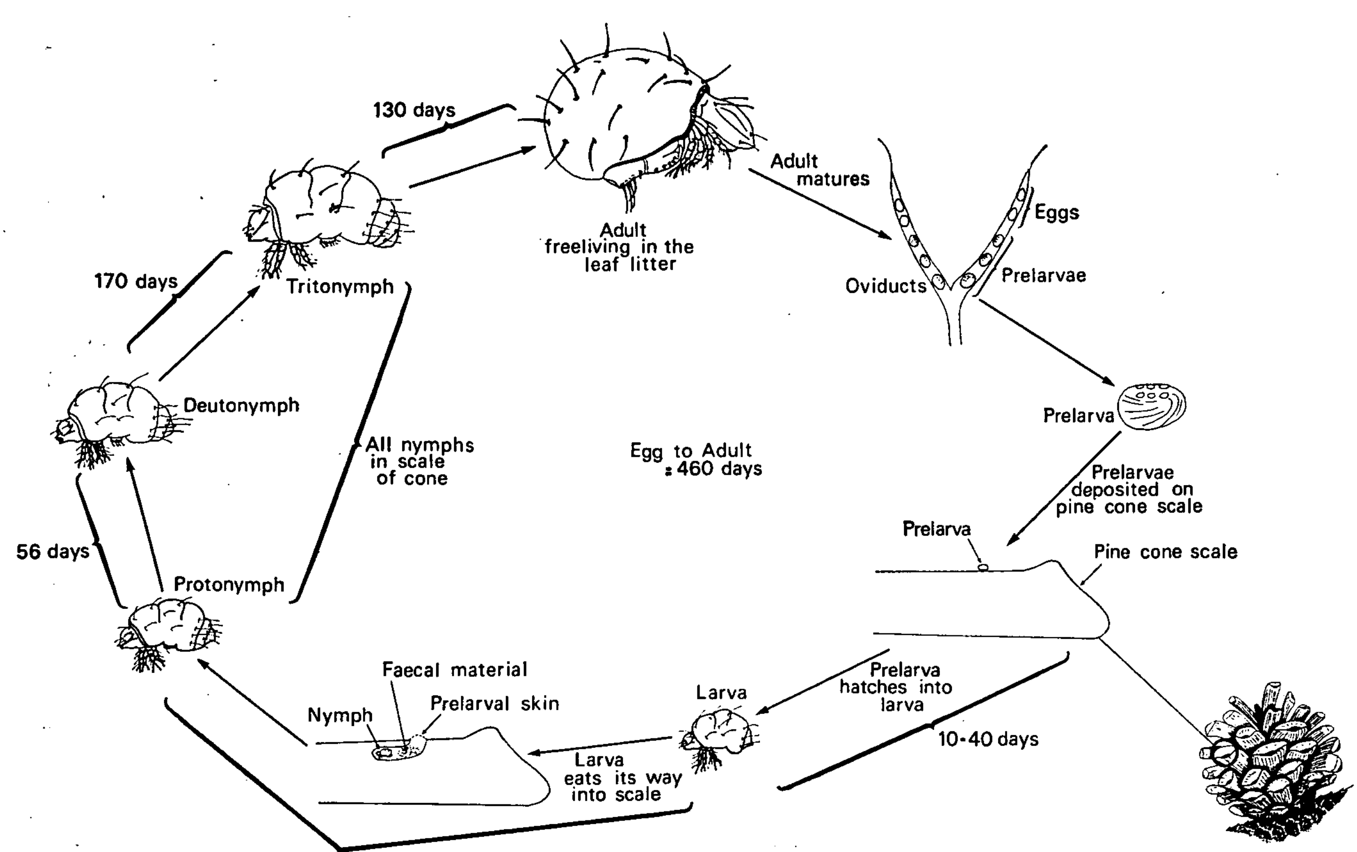

Figure 8 Life-cycle of Steganacarus magnus.

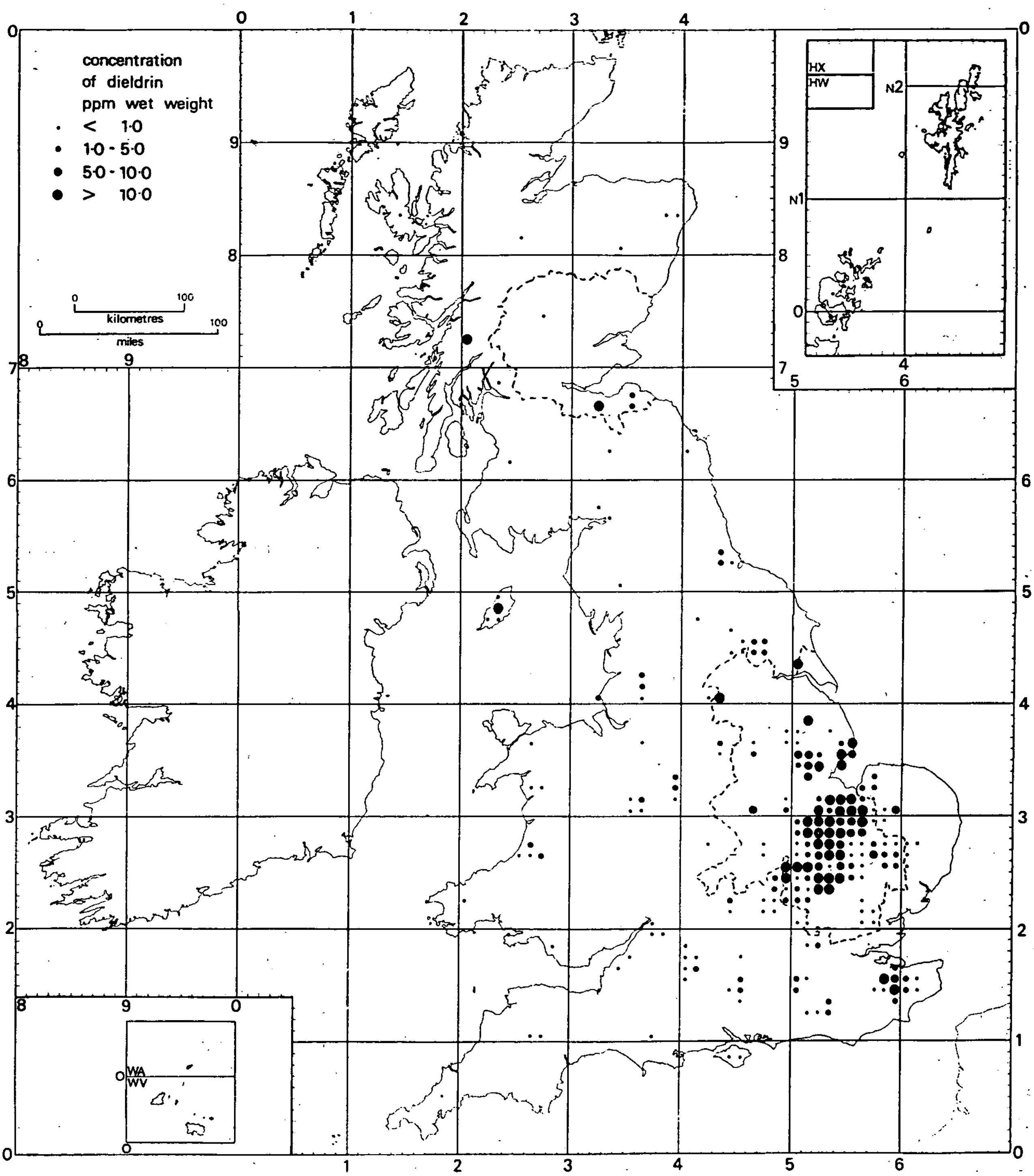

Figure 9 Dieldrin residues in the livers of 227 kestrels and Barn owls found dead during 1970–1973. Each bird is represented by a point on the map.

demonstrates deformities and changed behaviour in tadpoles at very low levels of exposure to DDT, possibly providing a useful monitoring tool in consequence. To explain all these effects, however, we also need to understand the working of the healthy animal or the unpolluted system, and R. K. Murton's research on seasonal rhythms and hormone cycles in birds will be developed in this direction. C. Newbold has been studying the effects of herbicides on flora and fauna in and around fresh-water ponds.

DIELDRIN RESIDUES IN THE LIVERS OF KESTRELS AND BARN OWLS FOUND DEAD IN 1970–73

One of the primary uses of dieldrin has been that of a cereal seed-dressing, particularly in areas suffering moderate to severe damage from the Wheat-bulb fly (areas within the discontinuous lines on the map, Figure 9). Work at Monks Wood Experimental Station has shown that predatory birds contain larger concentrations of persistent organochlorine insecticides than other groups of birds, and that declines in populations and breeding-success of some predatory species were caused by lethal and sublethal effects of dieldrin, which is one of the more toxic and persistent of these compounds. Two of the predators most affected, in areas of eastern England particularly, are the kestrel (*Falco tinnunculus*) and Barn owl (*Tyto alba*), species commonly frequenting agricultural land and rough grassland, and feeding primarily on small mammals. One hundred and fourteen dead birds have been received from this area, of which 31·5% had lethal concentrations of dieldrin (in excess of 10ppm wet weight) in their livers, while only 3·5% of the 113 specimens from other areas were so affected. Although the spring sowing of dieldrin-dressed grain has been subject to a voluntary ban since 1962, 90% of the total dieldrin casualties occurred in the period January–May; and only 10% in November–December. Continued investigation will monitor residue levels and consequent indirect mortality.

A. A. Bell

GEOGRAPHICAL VARIATION IN POLLUTANTS IN GUILLEMOT EGGS

In recent years seabird eggs collected under licence from a number of coastal sites have been analysed in order to identify those populations most heavily contaminated by certain persistent organochlorine and heavy metal pollutants. While this information was obtained primarily in connection with studies of possible sublethal effects of the pollutants on the birds, it has also provided useful comparative data on geographical variation in the levels of the pollutants themselves in coastal waters around the British Isles. In many seabird species, the pollutant residues in eggs fall within comparatively narrow limits for any one locality: this is particularly true for the more sedentary species such as the guillemot (*Uria aalge*) and those having relatively narrow food range. Adult guillemots breeding in Britain disperse over only relatively short distances in winter, occupy the same nesting colony throughout their lives, and feed on a limited range of fish, mostly small Clupeidae and Ammodytidae.

Examples of the broad geographical patterns of distribution of three pollutants, mercury (some of which occurs naturally, but also as an industrial pollutant); PCBs (organochlorine compounds previously used in industry); and DDE (the chief metabolite of the insecticide, DDT, found in avian tissue) are illustrated in Figures 10–12. The main feature is the proportionately higher levels of all pollutants in the Irish Sea region compared with eastern, and especially northern, colonies. This is particularly marked for mercury and PCBs, and is presumably connected with the slow rate of water exchange in the relatively shallow Irish Sea as well as the larger amounts of industrial waste and effluent it receives. In the most contaminated colonies, concentrations of mercury and PCBs are as high as, or higher than, in guillemot eggs examined from other parts of its world range. DDE concentrations, on the other hand, even in the Irish Sea, are some twenty times lower than in one Baltic colony and five to ten times lower than in a colony off the coast of California.

J. L. F. Parslow
D. J. Jefferies

PCB EFFECTS ON THE AVIAN THYROID

The effects of polychlorinated biphenyls (PCBs) on avian thyroid glands are being investigated as part of a long term study of the effects of marine pollution on seabirds. The thyroids control the metabolic rate, and their normal functioning is important for the successful completion of reproduction. The effect of PCBs on this endocrine system was first studied using Lesser black-backed gulls (*Larus fuscus*) dosed with Aroclor 1254 at rates from 50 to 400mg/kg/day. The thyroids of the treated birds were larger and heavier and their component follicles were bigger and contained more fluid (colloid). This histological picture suggests involution with minimal depletion of thyroid hormones. Small numbers of guillemots (*Uria aalge*), given low dose rates of Aroclor 1254, developed large colloid goitres like those of the gulls. Conversely, at

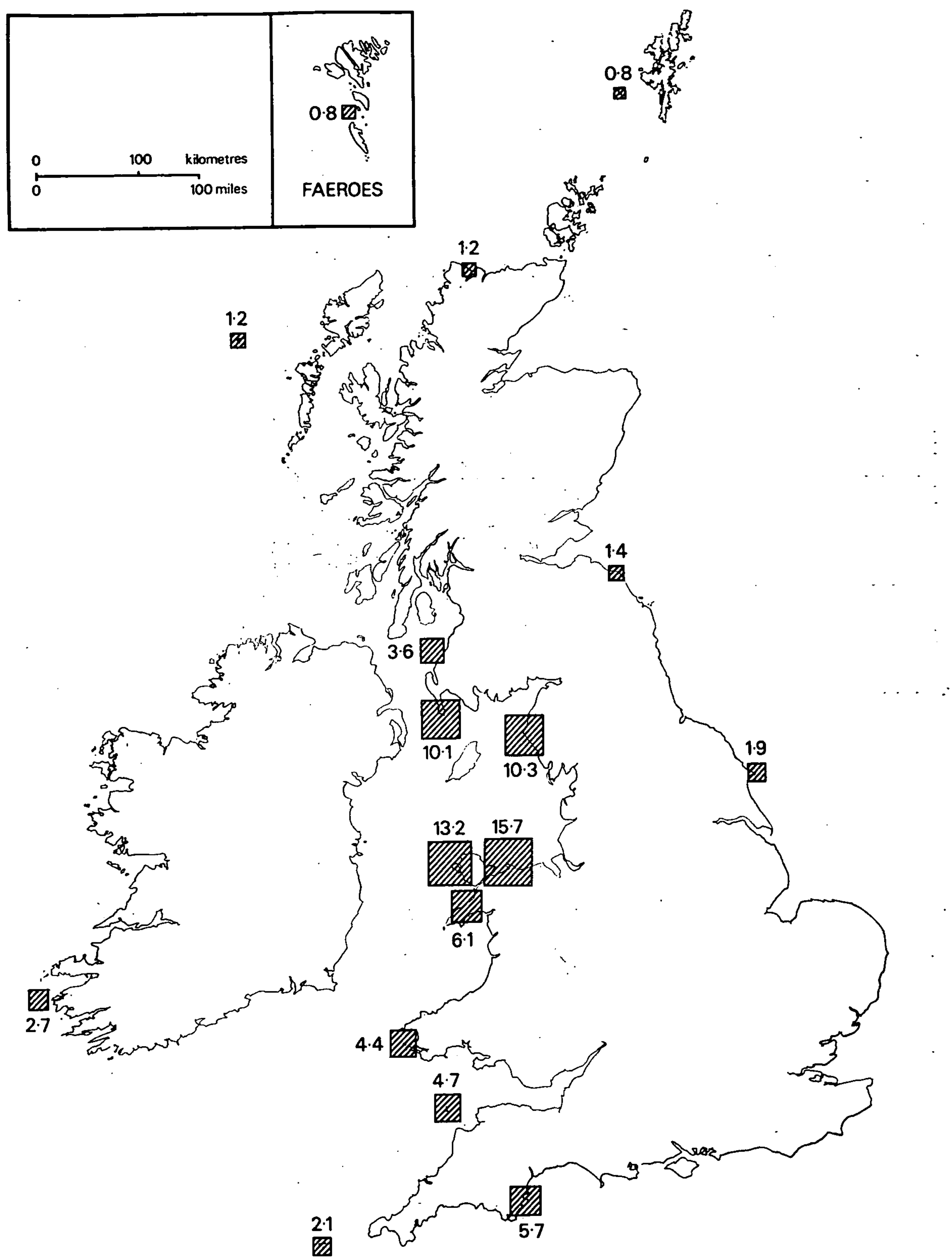

Figure 10 Mean concentration of mercury (ppm dry weight) in guillemot (Uria aalge).

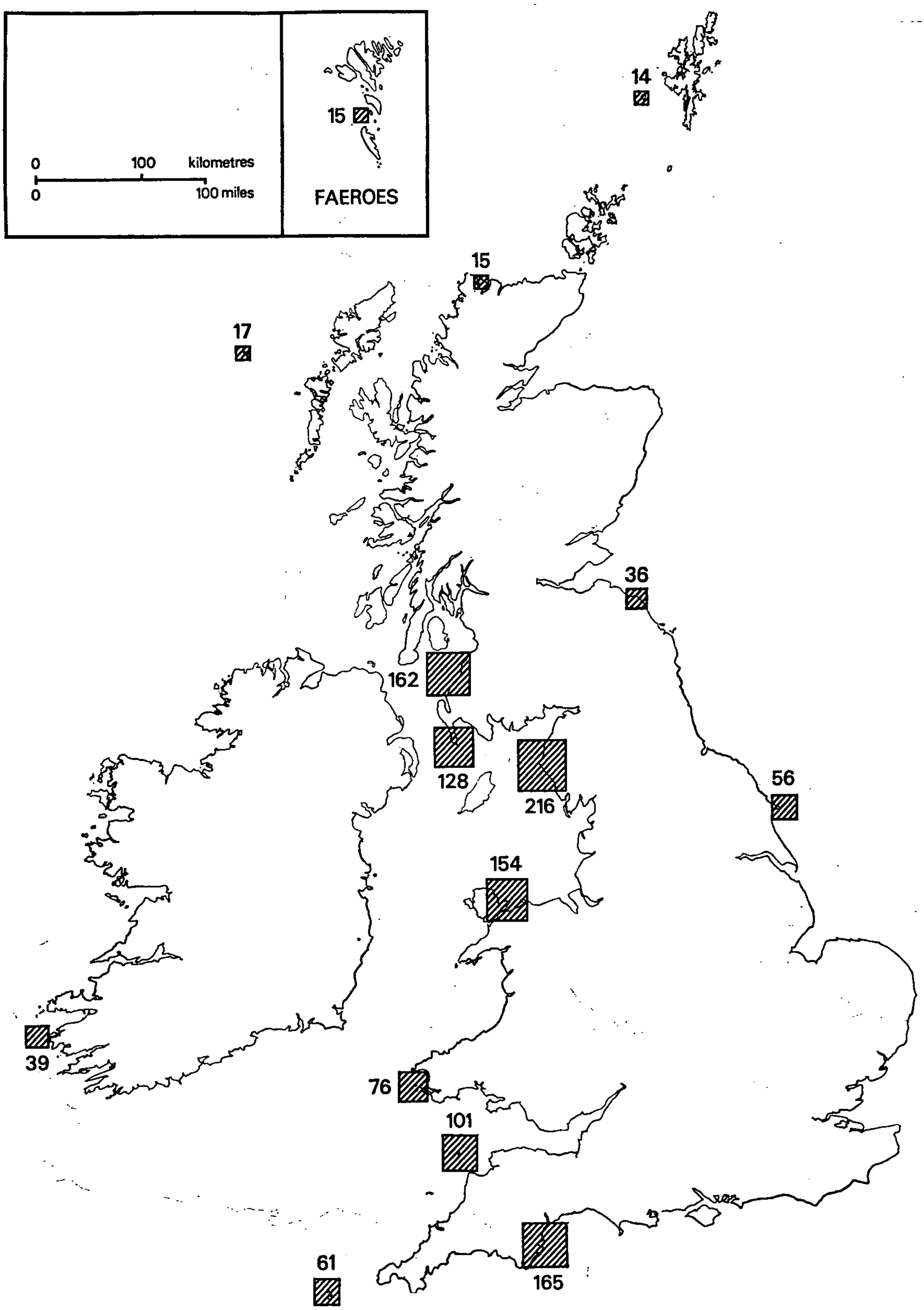

Figure 11 Mean concentration of PCBs (ppm liquid weight) in guillemot (Uria aalge) *eggs.*

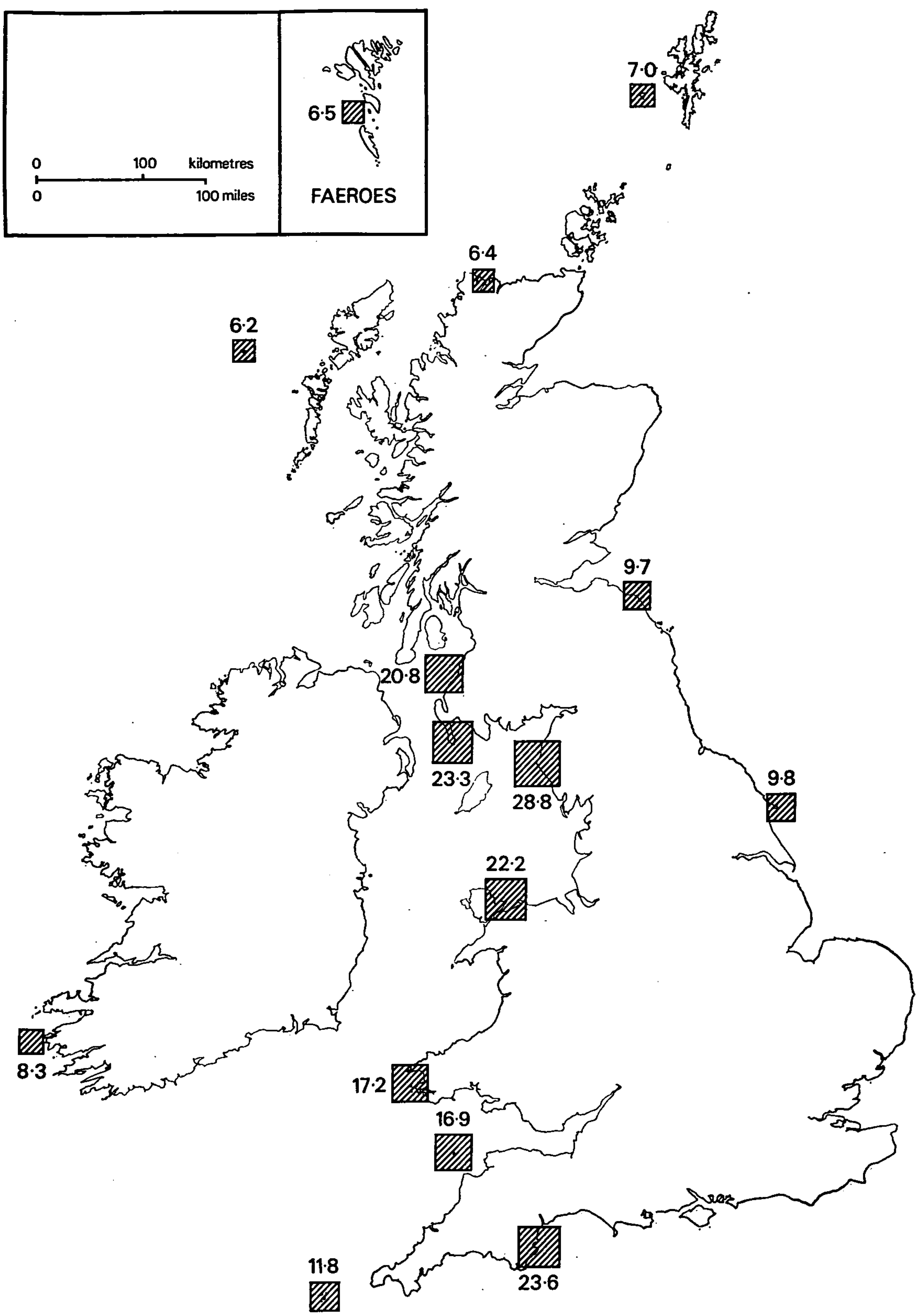

Figure 12 Mean concentrations of DDE (ppm liquid weight) in guillemot (Uria aalge) *eggs.*

dose rates of 400 mg/kg/day the thyroids were atrophied.

In warm-blooded animals thyroid activity is directly controlled by the hormone thyrotrophin (TSH) which is secreted by the pituitary. The relative amounts of TSH and thyroid hormone in the circulatory system are largely controlled by a negative feed-back system. Low levels of thyroid hormone in the blood act on the pituitary causing it to release TSH which subsequently causes the thyroid to release more thyroid hormones. If the output of TSH is very low the thyroid glands show involution and with no TSH the thyroids would atrophy. Thus the above changes suggest a direct effect of the PCB on the pituitary causing a decrease in the amount of TSH produced, according to the dose rates given. Both thyroid involution and atrophy would cause a state of hypothyroidism with a low metabolic rate in the animal concerned. This action on the pituitary producing secondary hypothyroidism could be the mechanism behind many of the sub-lethal effects of PCBs noted in the literature.

D. J. Jefferies J. L. F. Parslow

SUBLETHAL EFFECTS OF PESTICIDES ON FROGS AND TOADS

The part played by pesticides in recent population declines of the frog (*Rana temporaria*) and the toad (*Bufo bufo*) has been studied by carrying out surveys of population changes, toxicological studies in the laboratory and in the field, analysis of field specimens and studies of other factors. The work indicates that, although many sites have probably become harmfully polluted with pesticides since the 1940's, pesticides have been relatively unimportant as factors causing decline on a national scale. The loss or modification of wetland habitat has been the most important cause of changes in the abundance of frogs and toads.

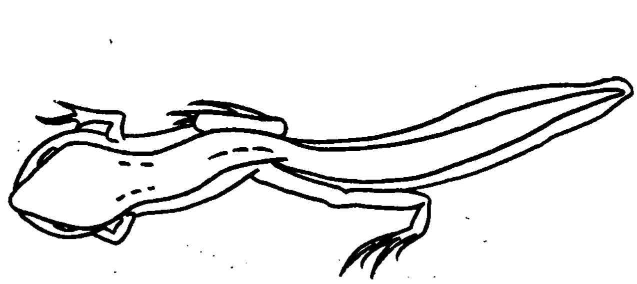

Figure 13 Sketch of a frog tadpole with a kink at the base of the spine and a permanently straight left leg. These deformities have been noted amongst tadpoles maintained in media containing as little as 0·0001 ppm DDT.

One of the most interesting aspects of this investigation has been the wide variety of easily-recognizable sublethal effects, particularly physical deformities and changes in behaviour, amongst tadpoles exposed to pesticides. For instance, frog tadpoles become conspicuously overactive if kept for one day in a medium containing initially 0·005 parts per million (ppm) DDT or 0·5 ppm dieldrin. Immersion in only 0·0001 ppm DDT can cause spinal kinks and perhaps straight hind legs (Figure 13). In the field, few tadpoles survive to become young frogs, mainly because of predation, and those rendered hyperactive or distorted by sublethal poisoning will probably be amongst the first to be eaten. In the laboratory, Warty newts (*Triturus cristatus*) were found to prey preferentially upon overactive DDT-treated frog tadpoles rather than on untreated tadpoles.

Sublethal effects, such as physical deformities and changes in growth rate and behaviour, have been used in field trials to assess the significance for tadpoles of standard applications of herbicides and insecticides. The feasibility of using obvious sublethal effects to detect pollutants and determine their significance is also being tested. One particular advantage of using tadpoles in this type of study is that they can be caught and examined in larger numbers than any other vertebrate.

A. S. Cooke

THE CIRCANNUAL RHYTHM OF BREEDING PERIODICITY IN BIRDS AND THE STABILITY OF OSCILLATOR SYSTEMS UNDER DIFFERENT *ZEITGEBER* SCHEDULES

It is now becoming established that breeding periodicity in birds is controlled by circannual rhythms in body functions, which are adaptively linked to the seasonal changes in day length. Gonad development is stimulated when different hormone rhythms become phased in a way that allows the synergistic stimulation of target tissues. The same applies to preparation for migration, including nocturnal restlessness, seasonal moult, lipid metabolism and a whole host of other metabolic functions. It is not yet clear how circannual rhythms are related to circadian rhythms, but they may be compounded from the same basic biological oscillators. When birds are kept on constant artificial photoperiods no controlling external oscillation (*zeitgeber*) is provided which can entrain the animals' endogenous rhythms and these now run free with a periodicity characteristic of each individual. The light part of the daily light–dark cycle also serves an inductive function in stimulating certain photoperiodic responses. If the daily light period is too short this stimulation may not occur.

In male passerine birds examined to date by other workers, starling (*Sturnus vulgaris*) and House finch (*Carpodacus mexicanus*) individuals kept for long periods of continuous long days (e.g. with 16 hours light and 8 hours darkness) undergo a rapid cycle of gonad recrudescence followed by involution and they then remain unstimulated indefinitely. This is probably because hormone rhythms cannot be re-phased to recharge the androgen-producing interstitial cells of the testes. Recent work with the Collared dove (*Streptopelia decaocto*) has revealed a unique response in that irrespective of the light regime – continuous dark (DD) for twelve months, light:dark ratios of 8:16, 12:12, 16:8 or continuous light (LL) – the birds underwent a gonad cycle of growth and involution lasting about 9½ months. Actually, the cycle was slightly longer in the birds receiving the most light, consistent with an expectation that a higher light intensity should increase the frequency of the endogenous rhythm. It seems that the oscillator system controlling breeding periodicity in this species is stable in its phase relationships when exposed to a wide range of light schedules – unlike the other species so far examined. We are concerned to explore the ecological significance of such differences in the biological clock of different species. In the wild in Britain, the 9½-month endogenous periodicity in the gonad cycle is entrained by the seasonal light cycle to 12 months. This results in the gonads being in a functional condition for 6 months and the actual breeding season lasting from mid-March until mid-September.

It is obvious that there are practical difficulties in studying the circannual oscillators controlling avian breeding cycles in a range of closely related species under controlled laboratory light schedules: the time span during which subjects must be held is a problem in itself in terms of the allocation of cage space. We are fortunate that a comprehensive collection of closely related swans, geese, and ducks (*Anatidae*) is kept by the Wildfowl Trust at Slimbridge, where all the birds are subject to the same seasonal *zeitgeber*, even though they originate from many different latitudes. In collaboration with Dr Janet Kear it has been possible to make comparative studies of the way breeding cycles – essentially cycles of egg-laying – vary depending on the latitude of origin; latitude is a measure of the light regime under which each species evolved. Our studies indicate a systematic pattern in the way the oscillators underlying the biological clock have evolved and adapted. It is clear that fundamental physiological contraints exist which limit the capacity of each species to adapt ecologically.

This area of research will be integrated into future programmes designed to understand how pollutants disrupt biological systems. It is already known that the toxicity of injected pollutants may vary in relation to seasonal lipid cycles and the mobilization of stored metabolites. Since such seasonal rhythms are controlled by biological clocks their involvement at this level needs definition. More significant is the likelihood that stress situations and pollutants may affect adrenal function, for corticosteroids are important phasers of biological rhythms in endocrine function and tissue sensitivity.

R. K. Murton
N. J. Westwood

THE EFFECTS OF HERBICIDES ON POND ECOSYSTEMS

Herbicides are being use extensively to control the growth of water plants in canals, ditches and pools, but very little research has been done on the effects of these herbicides on aquatic ecological systems as a whole. This study was undertaken to determine the short term and long term ecological effects of two commonly used herbicides, dichlobenil and diquat.

Six artificial pools were used, each 5·0m in diameter and 1·0m deep and old enough to have developed a diverse and fairly stable flora and fauna. In May 1972 two were sprayed with dichlobenil, two with diquat and two were left as untreated controls (see Plates 5–8).

The composition, standing crop and production of the vegetation and the abundance of the main species of aquatic invertebrates were followed throughout 1972, 1973 and 1974.

In both ponds treated with dichlobenil, the dominant angiosperms, plants such as reedmace (*Typha latifolia*), Creeping bent (*Agrostis stolonifera*), Water crowfoot (*Ranunculus trichophyllus*), and Water plantain (*Alisma plantago-aquatica*), were eliminated along with the large alga *Chara delicatula*. As the plants decayed, oxygen levels fell (but not to zero) and there were changes in nitrate-nitrogen, carbon dioxide, silica and ammonia levels. Filamentous green algae were checked initially, but blue-green algae and diatoms were unaffected and in one pond a filamentous algal 'bloom' ensued while in the other a diatom flora developed. In 1973 both ponds were dominated by filamentous algae and one showed a prolonged bloom. Angiosperms recovered in 1973 and 1974 (in one pond *R. trichophyllus* covered 80% of the surface), but the initial vegetation did not fully recover within the span of the experiment.

There were parallel faunal changes. As the vegetation decayed there was a dramatic fall in the abundance of the Cladoceran crustacean *Simocephalus vetulus*, which is associated with vegetation (from levels of $28{\cdot}6 \times 10^3$ and $16{\cdot}5 \times 10^3/m^3$ to $0.11 \times 10^3/m^3$) and a rise in the open water species *Daphnia longispina*. In 1973 the latter was also prominent in the clear centres of the ponds, but *S. vetulus* recovered as vegetation re-grew reaching $94{\cdot}3 \times 10^3/m^3$ in the pond where *Ranunculus trichophyllus* had attained 80% cover. The destruction and slow recovery of vegetation also affected other invertebrate species, including water beetles and dragonflies, although some bugs (Notonectidae) increased.

The higher plants in the pools treated with diquat also showed signs of decay four days after treatment. There was an algal bloom in only one of the two ponds. In 1973 *Chara delicatula, Typha latifolia, Potamogeton gramineus, Alisma plantago-aquatica* and *Ranunculus trichophyllus*, all original dominants, re-grew, along with algae. There was no discernible change in ammonia, nitrate, phosphorus, silica, sodium, calcium, potassium or magnesium levels in the water following herbicide treatment, but there was a slight fall in pH and an increase in free carbon dioxide.

The Cladoceran *Simocephalus vetulus*, present at the high levels of $3{\cdot}85 \times 10^4$ and $1.43 \times 10^4/m^3$ respectively before treatment, appeared to have been eliminated two weeks afterwards and copepod numbers also fell. Later, however, *S. vetulus* became abundant again, accompanying the growth of the alga *Mougeotia scalaris*, on which the animals were shown to feed. Following the destruction of the habitat provided by the higher plants, many of the invertebrates capable of flight left the ponds, but by September 1972, as vegetation recovered, Hemiptera and Coleoptera re-appeared. In 1973 there was little difference between the invertebrate faunas of sprayed and unsprayed ponds.

These experiments need extension and repetition, but do provide a starting point for predicting how particular fresh water systems will respond to herbicide treatment.

C. Newbold

Plant biology

The distribution and performance of plants and animals is often difficult to explain unless ecological studies are founded upon good taxonomy, and supported by the investigation of variation within species, and of basic genetics and physiology. The Subdivision of Plant Biology in ITE is concerned with all these aspects, and is particularly strong in expertise on the basic biology of trees.

The reports in this section cover an appropriately wide spectrum. S. W. Greene, with colleagues, has been investigating the taxonomy and reproductive physiology of mosses and liverworts under polar conditions. A. J. Gray and R. Scott have studied genetic variation in salt marsh plants, some of which may have unsuspected uses in roadside swards often treated with salt in winter. T. V. Callaghan has investigated intraspecific variation in the grass *Phleum alpinum* at the limits of its range. R. Scott is investigating the possibilities of using coastal grasses for road verges and maritime embankments instead of the usual agricultural grass mixes. A. S. Gardiner and N. J. Pearce report on studies of morphological and chemical variation in birch and elm. This work leads on to the physiological study of oak, described by K. A. Longman, and P. A. Mason and J. A. Pelham's research on mycorrhizal fungi associated with plant roots and probably vitally important for tree growth and nutrition. R. C. Warren documents another aspect of the association between fungi and bacteria and trees: the unseen but widely present growths that coat the surfaces of buds and leaves. A. M. Skidmore has worked on the cultural characteristics and pathogenicity of *Ceratocystis ulmi*, the cause of Dutch elm disease. J. I. Cooper has examined trees and shrubs in the 'natural' environment and concluded that they are liable to infections with several viruses that may pose a threat to other types of vegetation. M. G. R. Cannell looked at the morpho-physiological factors which limit wood yield in Lodgepole pine, Sitka spruce and Black cottonwood to help silviculturalists and tree breeders to use the inherent natural variations that exist among trees of one species. Pelham and Mason describe how they grew birch seedlings aseptically, so that mycorrhizal development could be excluded as a factor in breeding trees for nutritionally poor sites. R. R. B. Leakey, V. R. Chapman and K. A. Longman are developing techniques for growing and propagating cuttings of obeche, an important timber tree grown in West Africa. In this way it is hoped that the range of genetic variation among threatened tree species will be safeguarded.

THE ECOLOGY AND TAXONOMY OF BRYOPHYTES IN ANTARCTICA

The bryophytes, which comprise the Hepaticae (Liverworts), the Anthocerotae (Hornworts) and the Musci (Mosses), form one of the primary groups of the plant kingdom and play a modest, but not unimportant, role in the world's terrestrial vegetation, being widespread and prominent in the montane forests of the tropics, as well as in alpine and polar regions.

Current research projects on bryophytes involve investigations of their taxonomy, growth and reproductive responses to harsh polar environments. In Antarctica, where work is being done in collaboration with the British Antarctic Survey, mosses and lichens dominate the vegetation which forms a discontinuous cover over ground and rock surfaces. In climatically favourable coastal areas and on off-shore islands, closed communities many square metres in extent may be formed, where the net annual production of turf-forming or carpet-forming mosses may be surprisingly high (over 800g/sqm). Certain species decompose extremely slowly and some of the resulting moss peat banks are 2–3m deep. ^{14}C dating techniques have shown some recently exposed banks to be between 250 and 150 years old, while basal layers of others are about 2000 years old. Rates of net photosynthesis are generally low, and while some species have broad response curves in relation to light and temperature regimes, others have more narrowly defined optimal ranges, although evidence is being obtained that some species can acclimatize to abnormal conditions, if the latter are sustained for long periods. Marked differences have also been found in the ability of many mosses to recover from periods of desiccation and freezing, an important attribute in an environment where temperature at plant level may commonly pass through a diurnal cycle of 30°C, much of which may be below freezing point.

Reproductive response appears equally varied with few species being able to complete their life-cycle each year. Some fail to produce gametangia, while in others a breakdown of the normal development of sex organs may result in the species remaining barren in most seasons. Under experimental conditions, however, normal development may be obtained. Some bipolar species exist as physiologically distinct ecotypes, according to evidence obtained by comparing material from Greenland, Great Britain and the sub-Antarctic island of South Georgia. This is the first time that this has been shown in a moss.

Bipolar species also raise many interesting taxonomic questions, particularly over the nature and value of discriminating criteria. Virtually all of the early descriptive work on Antarctic bryophytes employed criteria developed from work with Northern Hemisphere floras. But it is now becoming clear that in the Southern Hemisphere many taxa are members of species assemblages with character distributions very different from their northern counterparts, so much so that distinct Southern Hemisphere criteria are having to be defined. Revisions are being undertaken of moss genera represented on South Georgia and in southern South America, and routine identification work is carried out for the British Antarctic Survey. A computer-based data bank of species and specimen-records is maintained and among its capabilities is the provision of data on type specimens and synonymy lists.

S. W. Greene

SALT MARSH GRASS CHROMOSOME NUMBER STUDIES

Multiplication of chromosome number can be linked with differences in growth form in many organisms. *Puccinellia maritima* is the most abundant and widespread grass of British salt marshes. It has been assumed that it contains individual races with different chromosome numbers corresponding with distinct growth forms, but we have been unable to find plants with any other chromosome number than 56 in root tip meristem squashes of plants taken from locations all round Britain, representing the full range of variability. Accepting the evidence that plants produce more seed when crossed with other individuals than from self-pollination, it appears that variation is the product of active interbreeding combined with environmental effects on individual plants, with no apparent chromosome number influence.

R. Scott
A. J. Gray

GENECOLOGY OF SALT MARSH PLANTS

It has become increasingly apparent over the past decade that the forces of natural selection are often sufficiently powerful to maintain genetic differences which arise within local populations of flowering plant species in response to environmental variability. Such differences may be preserved over very small distances and despite continued interbreeding between the genetically different individuals. It is therefore not surprising that salt marshes, highly heterogeneous environments where habitat factors vary both along linear gradients and in mosaic patterns, contain species such as *Aster tripolium*, *Suaeda maritima* and *Halimione portulacoides* which exhibit high within-species variation, much of which is both habitat-correlated and heritable (Gray, 1974).

Puccinellia maritima is the most abundant and widespread grass species on British and European salt marshes, occurring both as a colonist of bare mud and as a major component of the developing marsh sward. It covers very large areas of grazed salting pastures. The first stage of a study of intraspecific variability has been completed in which a subsample (57) of individuals collected from over 300 field sites around Britain in 1971 was grown in collateral cultivation conditions. Seven single-tiller replicates of each clone were grown individually in pots of ordinary soil arranged in a randomized split-block design and a total of twenty-two characters (e.g. tillering rate, leaf length, date of anthesis, inflorescence height) measured during growth and flowering. Correlation coefficents were calculated between all possible pairs of characters and the resulting matrix subjected to a principal component analysis (PCA).

The use of PCA in this investigation (see Figure 14) has provided a general model of variability in the species, simplifying the data so as to suggest hypotheses. It has also facilitated the selection of a number of contrasting biotypes for use in studies of the breeding system, the genetic basis of the variability, and the adaptive significance of particular growth forms. In addition characters have been selected from closely correlated groups and only these measured in the current investigation of local population differentiation, significantly saving time and effort. Finally the PCA has highlighted the correlation with habitat of certain growth forms, as illustrated in Figure 14 by the distribution on the first two components of biotypes from grazed marshes.

A. J. Gray
R. Scott

Reference: Gray A. J. (1974). The genecology of salt marsh plants. *Hydrobiol. Bull.*, **8**, 152–165. Proc. Int. Symposium. *(Hydrobiol. Bull.)* 'Ecology & Physiology of the Brackish Environment'. Amsterdam.

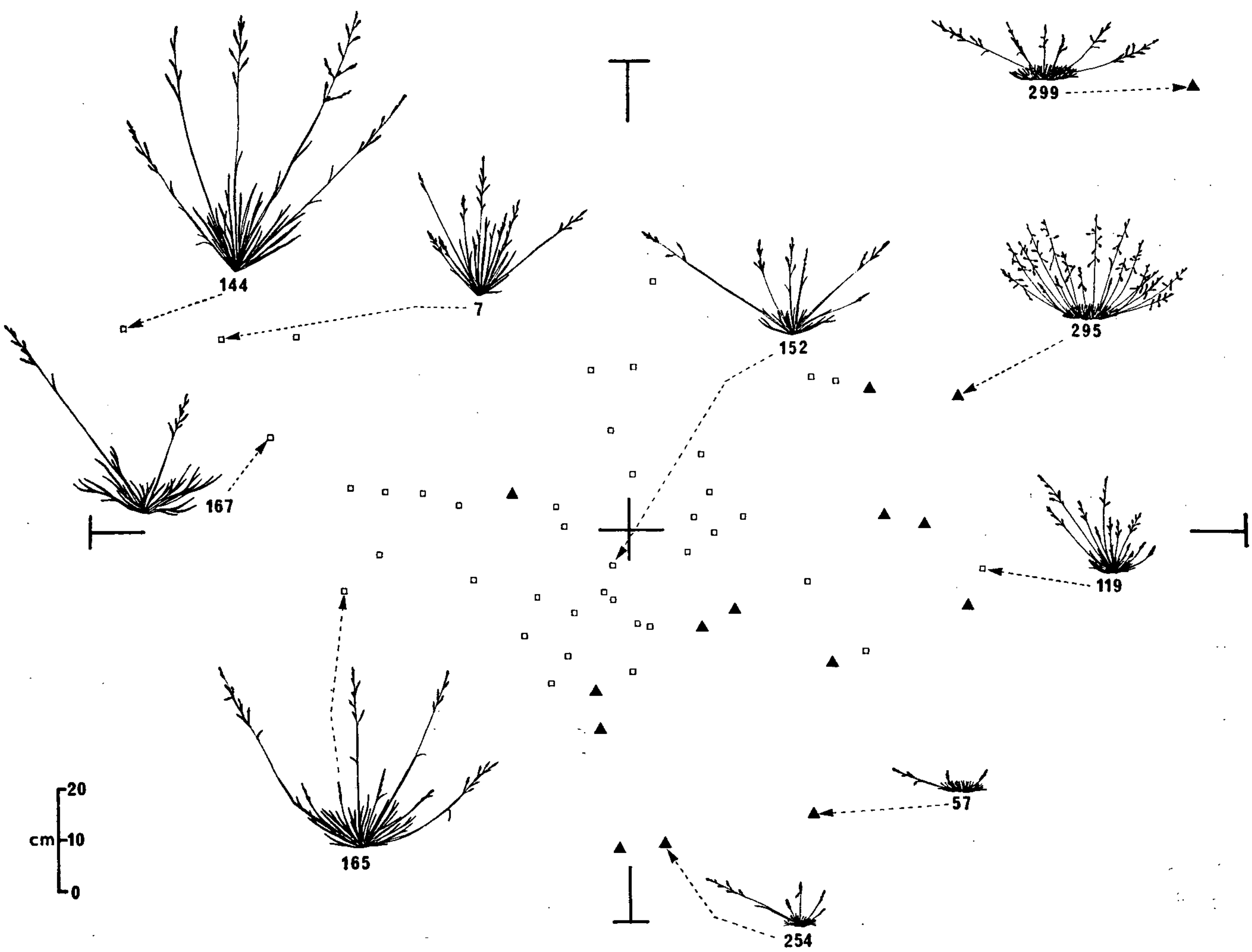

Figure 14 Projection of Puccinellia maritima *phenotypes on to the first two components of a principal components analysis (using twenty-two growth characters). Taken together the two components define a trend from large plants with small numbers of tillers (left) to small plants with high numbers of tillers (right). The plants are to scale; numbers are accession codes. The plants marked by triangle were collected from grazed salt marshes.*

INTRASPECIFIC VARIATION IN *PHLEUM ALPINUM* L.

One would expect the survival of a species at the limits of its geographical range to be finely balanced, where adverse environmental changes have to be accommodated by the species to avoid its elimination. Unlike animals, which can move to more favourable conditions, plants must remain and adapt to the new environment. This adaptation may be temporary as a result of the plasticity of developmental and physiological processes. Alternatively it may become permanent when two populations at opposite ends of the parent population's plastic range become genetically distinct, each with its own characteristic plastic ranges.

In a study into these processes, a grass *Phleum alpinum* was observed at its northernmost distributional limits (Disko Island, West Greenland) and at its southernmost (sub-antarctic South Georgia). On Disko Island the species was restricted to one habitat. Not only was genotypic variation absent, but the one genotype showed very small plastic ranges. One of the results of this was a rigid flowering cycle which enabled seed-set in only infrequent long growing seasons.

The subsequent population explosions and die-back indicate a very unstable system. At this site, therefore, the survival of the species is finely balanced and at the limit of its own genetic resources. On South Georgia, however, there is considerable variation with different genotypes occurring in most habitats. Each of these genotypes shows plasticity and seed is set annually. In the stable system on South Georgia the evolutionary limit found on Disko Island does not exist, and if there were land farther south, one or more forms of the species would undoubtedly grow there.

T. V. Callaghan

DEVELOPMENT OF GRASSES FOR AMENITY USE

Highway engineers and coastal protection authorities have begun to realize that many of the grass mixtures used for banks and verges are unsuitable for their long term tasks. The usual species are agricultural grasses bred for their yield criteria, which often have little relevance to soil stabilization or economy of management. The value of coastal grasses as alternative species giving greater persistence of cover and requiring less management is being examined. The performance of a range of species is being compared with that of conventional seed mixtures in field trials, over two habitats influenced by salt – a roadside and a maritime embankment. Early results indicate that the coastal grasses are persistent, and germination and cover are as good as in some of the bred varieties of turf grass.

A. J. Gray R. Scott

BIRCH: INTROGRESSION BETWEEN THE SILVER AND PUBESCENT SPECIES IN DEESIDE

The relationships and status of individual trees in a birchwood at Glen Gairn containing both Silver birch (*Betula pendula*) and Pubescent birch (*B. pubescens*) have been examined using a simplified method of assessing leaf-shape, based on the projection of leaf images on to a prepared grid. Research carried out by the Departments of Botany and Forestry, Aberdeen University, at Glen Gairn had already pointed to the occurrence of introgression between the two species; the ITE study was aimed at examining the effects of such hybridization on leaf-shape in which both species display marked differences. A principal component analysis illustrated that the problem could be reduced to two dimensions, and a graphical representation of the results divided the sample trees into two groups which corresponded with the two species. A greater degree of within-group variation in basic leaf-geometry was exhibited by the trees classified as *B. pubescens* than by those belonging to the *B. pendula* group (see Figures 15 and 16). The taxonomic distance between the boundaries of the two groups was very short and the positions occupied by some of the trees would support a theory of introgression. A comparison with two separate woods in Deeside in which each species respectively was adjudged to be growing in a relatively pure state confirmed the indications that the gap between the species had been narrowed in the case of Glen Gairn. So far the study has done little more than uphold the suspicions of introgression and more fundamental work will be required to clarify the situation. With a growing interest in birch variation both within and outside the Institute, plans for further studies are being explored.

A. S. Gardiner

CHEMICAL TAXONOMY: DEVELOPMENT OF METHODS FOR USE WITH ELMS

With the recent outbreaks of the aggressive form of Dutch elm disease (*Ceratocystis ulmi*) has come renewed interest in the taxonomic status of the British elms (*Ulmus* spp.) especially insofar as this is involved in identification of disease resistant material. To this end, work has been in progress at Merlewood on the development of methods suitable for characterizing elm material in terms of its enzyme complement – a technique now well established in this field of work.

Initial difficulties in preparing repeatable extracts of fresh plant material, which still retained sufficient detectable enzyme activity, have now been overcome by the preparation of powders of dehydrated leaf material made by homogenizing in ice-cold acetone. Such powders may be stored in a deep freeze for several months with no detectable loss of enzyme activity. The different molecular forms of each enzyme are separated by electrophoresis on acrylamide gels and when appropriately stained give, in many cases, patterns of activity characteristic of the tree from which they came.

Many enzyme systems have been detected, but work in future will concentrate on the peroxidase and cytochrome oxidase groups, as these now appear most likely to give useful discriminations between the elms.

Material has been collected from plants of a wide taxonomic spectrum, grown at Edinburgh University by Dr A. M. Skidmore, to enable studies of within-clone, between-clone and between-species variations to be started. Additionally material is being grown from seed at Merlewood to study both within- and between-seed lot differences.

Although work at present is confined to elms it is hoped that future work will see the techniques extended to the chemical taxonomy of the birches (*Betula* spp.) and be used to study the relationships between the two main species and their hybrids.

N. J. Pearce
A. S. Gardiner

PHYSIOLOGY OF THE OAK TREE

A review of the physiology of oaks has highlighted the 'stop–go' process of shoot extension. No sooner have fresh leaves and stems been produced in the spring than growth stops, apparently because it is inhibited by the new shoots. After a month or so, growth re-starts, with the 'stop–go' process sometimes repeated as many as four times in a season. If oak seedlings are placed in summer conditions in a growth cabinet, they may make as many as sixteen successive flushes of shoot growth. It is not entirely clear what controls this intermittent growth habit, which is more typical of tropical trees than of our other woody species in

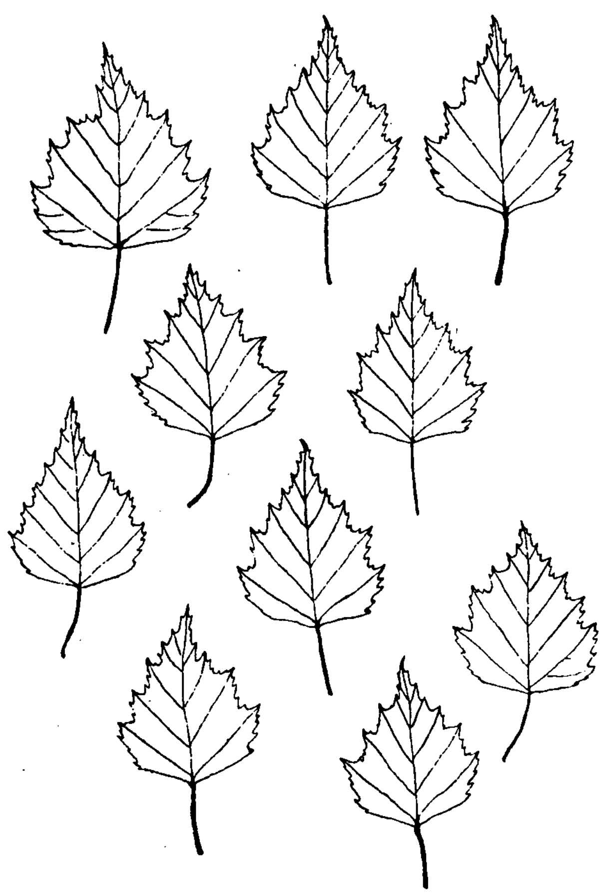

Figure 15 Birch: introgression between silver and pubescent species in Deeside. Silver birch (B. pendula).

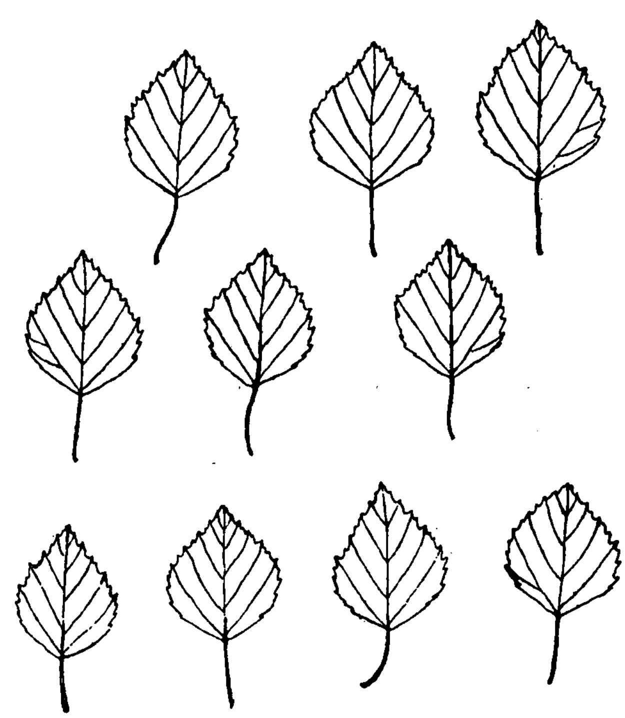

Figure 16 Birch: introgression between silver and pubescent species in Deeside. Pubescent birch (B. pubescens).

Britain, but it appears to involve both a response to the external environment and also changes in growth substances within the buds. Hormones found in unfolding oak buds can be used to stimulate the growth of buds of ash.

The first cells formed during the spring in the wood of oak are unusual in that they may grow to 500 times their original size, and water can then pass through them at up to 12 mm a second. Oaks can also have strange features such as the retention of withered, brown leaves during the winter, together with the active shedding of twigs 25 to 50 cm long.

K. A. Longman

SYNTHESIS OF MYCORRHIZAS IN CONTROLLED CONDITIONS

Plants often enter into balanced symbiotic relationships with microbes in which both partners contribute to the well-being of the other. Of these, mycorrhiza (plant/fungi) and legume nodules (plant/bacterium) are the best known. Intensive studies on the latter have already demonstrated that both the host and bacterium (*Rhizobium* spp.) control the formation and subsequent activity of legume nodules and with this knowledge techniques have been developed in which legume seeds are inoculated with highly effective strains of *Rhizobium*, so increasing yields.

Although sheathing mycorrhizas have been studied for many decades, the factors controlling their formation are still poorly understood. With this in mind a screening test has been developed to identify variation within the fungal and plant components of the symbiotic complex, the work being focused on birch (*Betula verrucosa*) and the Fly agaric (*Amanita muscaria*). Roots of aseptically germinated birch seedlings growing on an agar medium containing plant nutrients, glucose and thiamine hydrochloride are each inoculated with a piece of agar inoculum (1–2 sq mm), the seedlings being inspected six to eight weeks later. Experiments testing different seedlots of birch and a range of *A. muscaria* isolates indicated that host and fungal genotypes affected the formation of sheathing mycorrhizas and that this interaction was influenced by the nutrient status. In addition to influencing numbers of mycorrhizas per seedling, *A. muscaria* controlled the pattern of mycorrhizal branching. Some isolates stimulated the development of few but repeatedly branched mycorrhizas, whereas others stimulated the development of many which were sparsely branched.

These observations suggest that the genetical control of sheathing mycorrhizas has features in common with the legume *Rhizobium* complex, but the effects obtained in highly controlled conditions need to be reproduced in the field before initiating a tree improvement programme specifically aimed at facilitating the development of beneficial mycorrhizas.

P. A. Mason
J. Pelham

MICROBIAL ECOLOGY OF BUDS OF DECIDUOUS TREES

Many parts of the surfaces of trees support an epiphytic growth of fungi and bacteria. Buds have been shaken or homogenized in water and the resulting suspensions spread on to selective media. Numerous fungal and bacterial colonies then develop. In other tests where outer sheathing scales and inner young leaves were separated the buds fell into two categories: those of beech, oak, sycamore, elm and horsechestnut with microbes confined to the outer scales and in contrast those of ash and lime, with microbes contaminating the inner covered scales and young leaves, in addition to the outer scales.

Bud microfloras were similar to those found on senescent leaves and petioles in autumn, and were dominated by white yeasts (*Cryptococcus* spp.) with pink yeasts (*Rhodotorula* spp. and *Sporobolomyces* spp.) and *Aureobasidium pullulans* occurring consistently. Other fungi, not typically associated with leaves, were sometimes numerous. For example, *Rhinocladiella mansonii*, more commonly regarded as a human or animal pathogen, was isolated from buds of ash. Yeast-like stages of smut fungi were found in ash and lime buds whereas lime buds often yielded conidial stages of sooty-mould fungi (*Capnodiaceae*). Numbers of viable fungal propagules isolated per bud scale ranged from $2{\cdot}0 \times 10^3$ in elm to $6{\cdot}0 \times 10^3$ and $9{\cdot}0 \times 10^5$ on beech and ash respectively; the fungi on ash appeared in the indentations in the convoluted surfaces of the bud scales.

Compared with bud populations of fungi, numbers of bacteria fluctuated more extremely. Bacteria were sometimes absent from internal parts of buds from which fungi were isolated but were never detected when fungi were absent.

R. C. Warren

CULTURAL CHARACTERISTICS AND PATHOGENICITY OF *CERATOCYSTIS ULMI*, THE CAUSE OF DUTCH ELM DISEASE

(Work carried out under contract placed with University of Edinburgh)

Two cultural variants of *Ceratocystis ulmi* have been described; one is relatively slow growing and waxy, and the other rapidly growing and fluffy. The former is typical of endemic and non-aggressive isolates, whereas the latter is characteristic of aggressive cultures found in recent epidemic outbreaks (Gibbs and Brasier, 1973). During 1974, Takai associated aggressiveness with the production of cerato-ulmin, an unstable crystalline compound which when injected into elms caused many of the familiar symptoms of Dutch elm disease.

In collaborative experiments done with Mr D. K. Barrett, Commonwealth Forestry Institute, Oxford University, a third cultural variant, a feltoid-type, was identified during the year. It occurred as sectors in fluffy cultures, and was perpetuated when transfers from individual coremia (spore-producing structures) were cultured on blocks of elm wood. Although the feltoid types do not produce cerato-ulmin, they are nonetheless aggressive, causing leaf yellowing and necrosis, and stem dieback equal in severity to the damage done by fluffy cultures. It seems therefore that cerato-ulmin production is a poor indicator of aggressiveness.

A. M. Skidmore

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VIRUSES OF HARDWOODS

(Work carried out under contract placed with University of Oxford)

A virus, serologically related to isolates of cherry leaf roll virus (CLRV) from *Prunus avium, Rheum rhapontium* and *Sambucus nigra,* was isolated from *Betula verrucosa* growing on heathland sites in Berkshire, Oxfordshire, Lincolnshire and Leicestershire. During summer these trees had leaves with either mild chlorotic blotches or ring and line patterns, but by autumn the symptoms intensified to bright yellow. These symptoms were reproduced when seedlings of *B. verrucosa* were inoculated with CLRV, their development being similar irrespective of the source of virus (*B. verrucosa, S. nigra* or *P. avium*). Virus-like particles measuring 30 nm (diameter) were found in tubular structures in cell wall projections which were not observed in healthy trees.

It has been claimed that some soil-living nematodes, *Xiphinema* spp., are natural vectors of CLRV, but the naturally infected *B. verrucosa* were growing in the absence of these nematodes. The virus was, however, detected in one of thirty-nine seedlings from a virus-infected *B. verrucosa*, and herbaceous hosts inoculated with extracts of birch pollen became infected with the virus (see Plate 16). Serological tests indicated that a birch isolate of CLRV had a greater number of antigenic determinants in common with an isolate from cherry than with isolates from either *S. nigra* or *R. rhapontium.*

Viruses having soil-inhabiting nematode vectors were frequently detected in other woody perennials. Arabis mosaic virus, naturally transmitted by the nematode *X. diversicaudatum*, was consistently transmitted from leaves of *Fraxinus americana, F. excelsior* and *Ligustrum* spp. with pale green ring or line patterns (see Plates 17 and 18). Tomato black ring virus, transmitted by *Longidorus* spp. was isolated from leaves of *Laburnum anagyroides* with pale green chevrons and raspberry ringspot was isolated from *Forsythia sieboldii suspensa* leaves with yellowing veins. Clearly trees and shrubs in the 'natural' environment are liable to infections with several viruses that may adversely affect regeneration and pose a threat to other types of vegetation.

J. I. Cooper

INHERENT PHYSIOLOGICAL AND MORPHOLOGICAL DIFFERENCES FOUND WITHIN SPECIES OF FOREST TREES

Inherent differences that occur naturally amongst trees of one species can be exploited by sylviculturists and tree breeders to increase wood yield. But to do this effectively information is needed on morpho-physiological factors that underlie the inherent variation. These factors are being examined in Lodgepole pine (*Pinus contorta* Dougl.) which forms 20% of current Forestry Commission plantings, Sitka spruce (*Picea sitchensis* Bong. Carr) which forms 50%, and Black cottonwood (*Populus trichocarpa* Torrey and Gray). All these species are native along the western seaboard of North America.

Early experiments with differing provenances of Sitka spruce and Lodgepole pine suggested that growth rate differences could not be attributed to differing rates of net photosynthesis per unit of foliage. For example, the foliage on some slow-growing trees with northerly and/or high altitude seed origins seemed to photosynthesize more rapidly during Scottish summers than that on fast-growing trees with southerly seed origins. Instead the differing growth rates were more clearly related to the amounts of foliage. Attention was therefore focused on shoot morphogenesis.

Measurements of shoot growth 'components' on six provenances of 9-year-old Lodgepole pine, and five provenances of 8-year-old Sitka spruce, growing on two sites in Scotland, showed that the differing amounts of needle tissue produced by the trees did not arise

Plate 9 Brown hairstreak butterfly (Thecla betulae L.) *Photograph J. Thomas.*

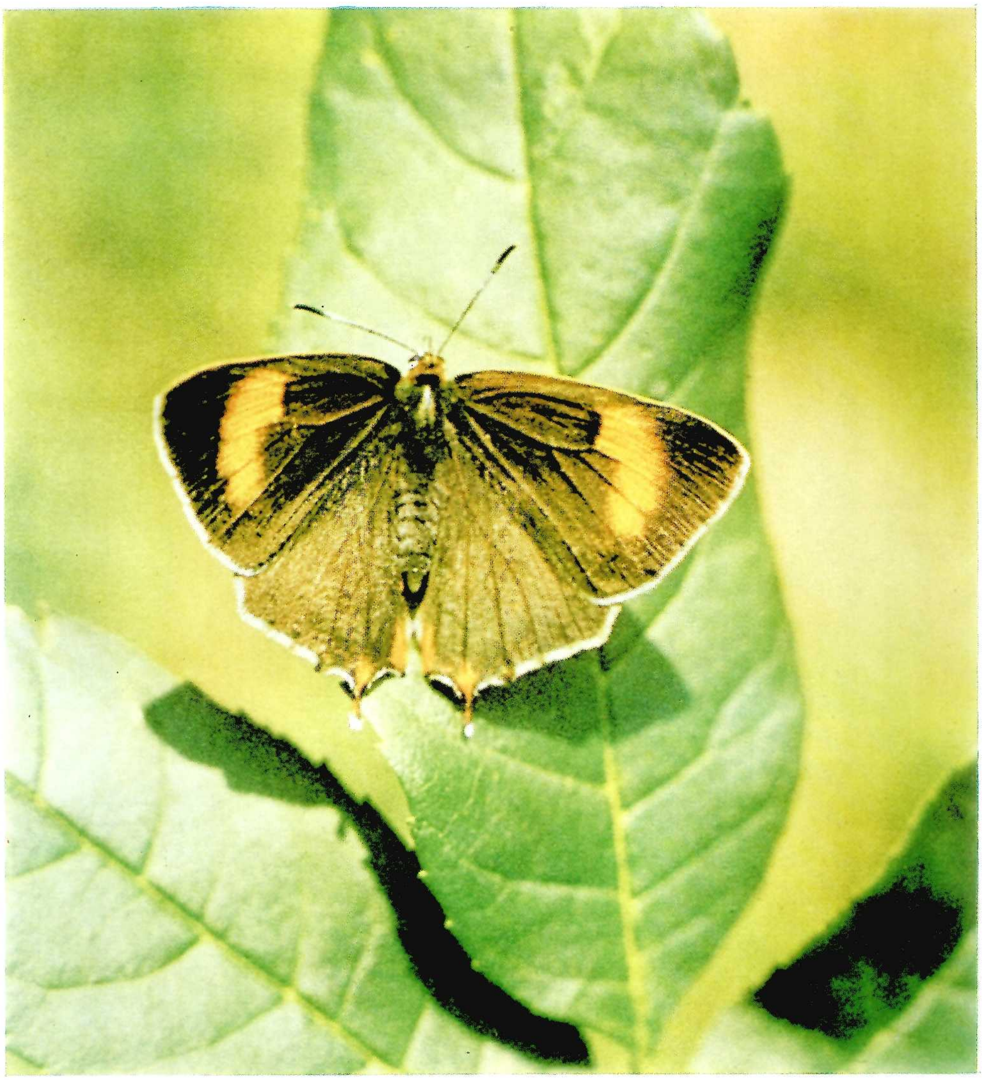


Plate 10 Brown hairstreak butterfly (Thecla betulae L.) *egg. Photograph J. Grant.*

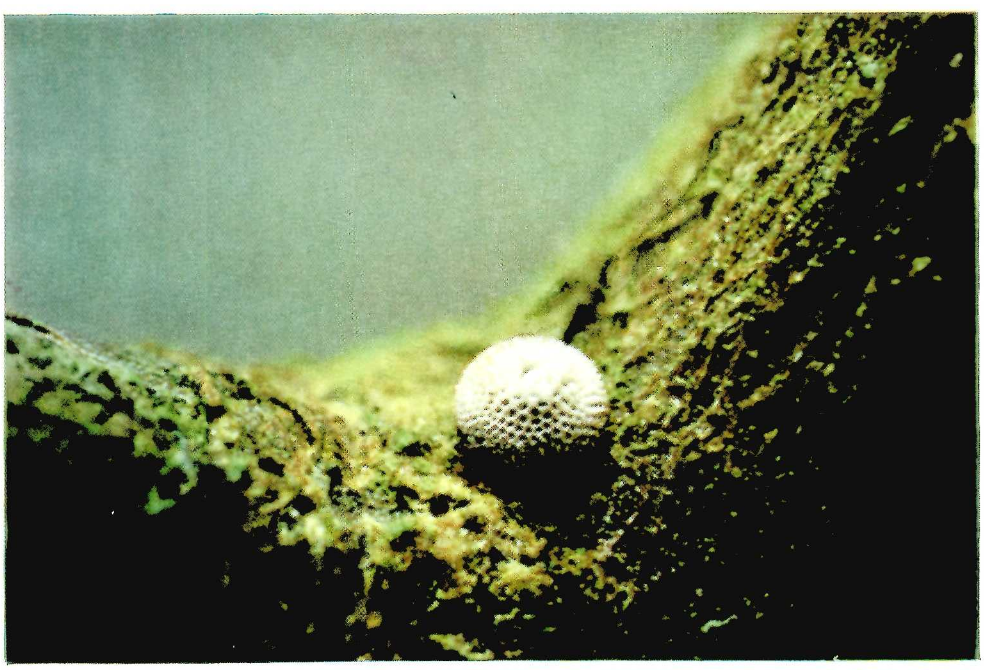
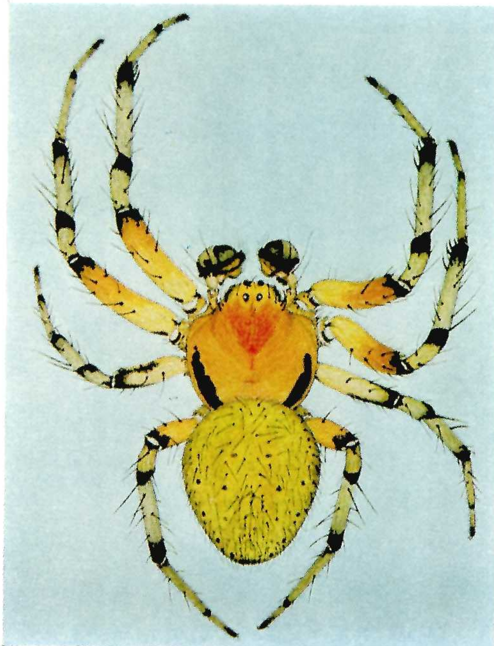


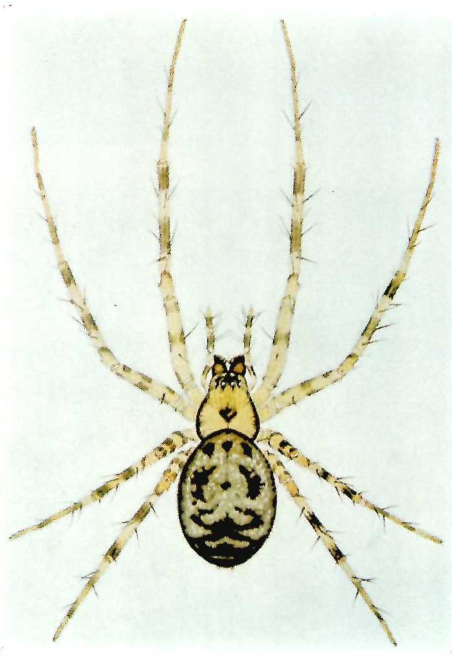
Plate 11 Furzebrook Research Station recently celebrated its twenty-first Anniversary. Part of its Open Day display was a series of paintings showing the range of form and behaviour of the major spider families. These are reproduced here, with the kind permission of the artist, Dr M. J. Roberts.

WEB SPINNING SPIDERS

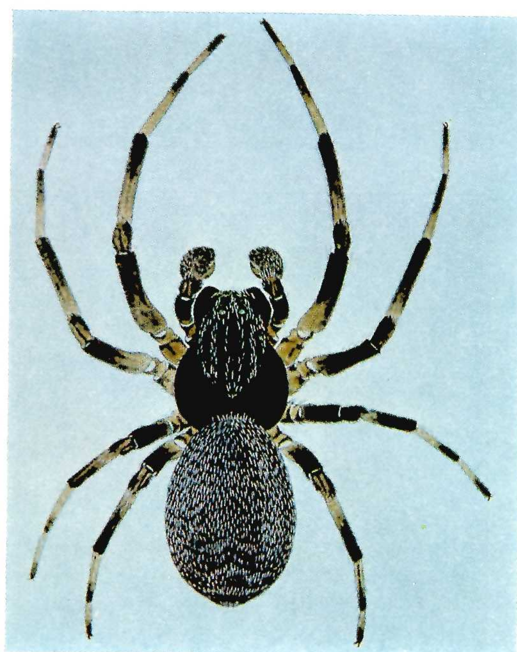


Family ARANEIDAE
1 *Araneus cucurbitinus*
Spins orb web.
Related to common Garden spider.

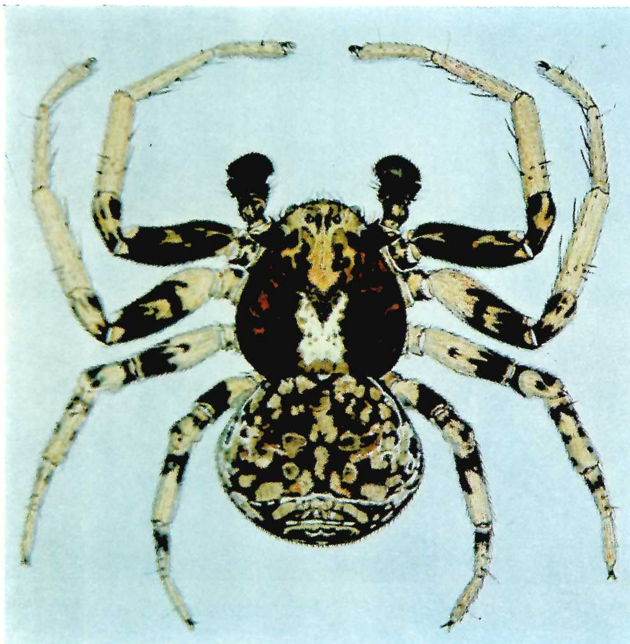
Family THERIDIIDAE
2 *Theridion sisyphium*
Builds large irregular web on bushes.
Mother feeds young by regurgitation.
Many theridiids feed on ants.



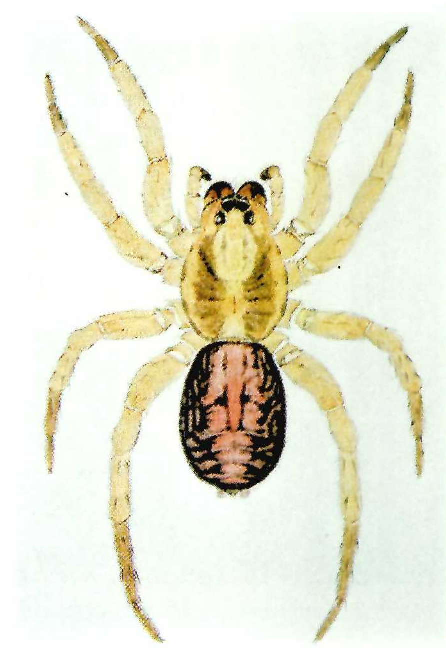
Family LINYPHIIDAE:
subfamily LINYPHIINAE
3 *Labulla thoracica*
Spins large and horizontal sheet web, often in hollow trees. Spider hangs below sheet, and pulls prey through.



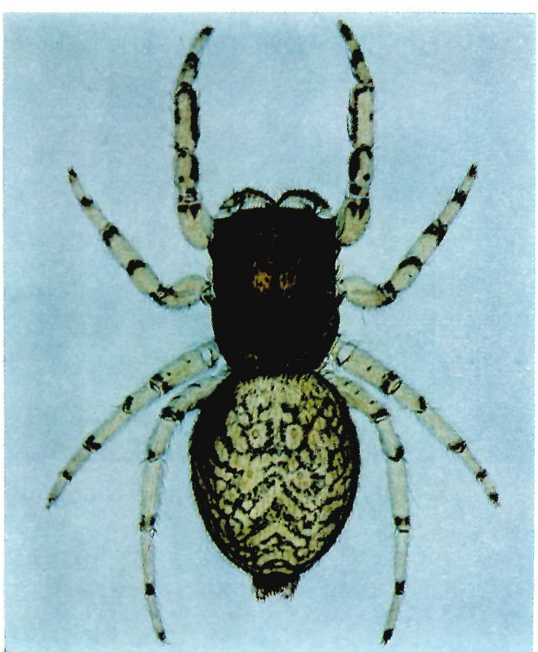
Family DICTYNIDAE
4 *Dictyna latens*
Builds small tangled web, often on gorse.



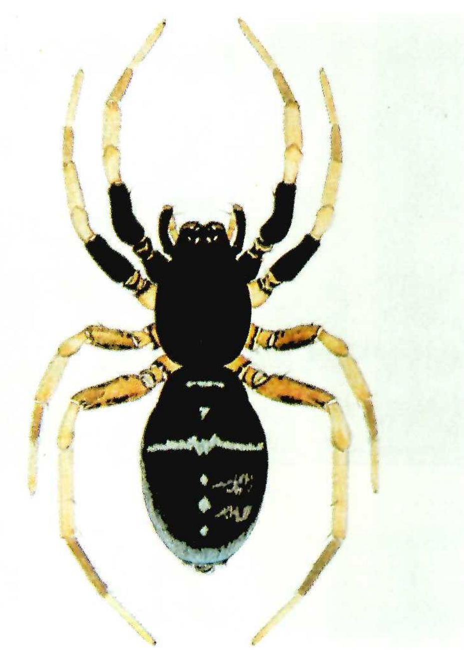
Family THOMISIDAE
5 *Oxyptila practicola*
Crab spider, hunts by lying in wait for its prey.



Family LYCOSIDAE
6 *Trochosa terricola*
Wolf spider. Most lycosids have good sight and hunt by chasing prey, but *Trochosa* is largely nocturnal and less active. Courtship rather like salticids.



Family SALTICIDAE
7 *Neon reticulatus*
Jumping spider, very good vision, hunts by stalking and leaping on prey. Has complex visual courtship display.



Family GNAPHOSIDAE
8 *Micaria pulicaria*
Ant mimic, lives in company with ants, and waves front legs like antennae. Active in sunshine, runs jerkily like ant.


Plate 12 Brindistir croft and cottage.


Plate 13 West Yell, Yell Sound, Ness of Sound.


Plate 14 Noss from Barahead, Bressay.


Plate 15 Lerwick oil rig in Brei Wick.

Photographs C. Milner.

from differences in needle sizes or numbers per unit length of shoot. They were overwhelmingly determined by the lengths of needle-bearing branch produced per tree, which in turn, reflected differences in numbers of lateral branches formed per unit length of shoot, and differences in overall height growth.

Thus, southern coastal provenances of each species had grown taller and produced proportionately longer branches than northern and/or inland provenances. The numbers of lateral branches that developed on the leaders, and on the first, second and third order lateral branches, were directly proportional to the lengths of these shoots, and these relationships differed between provenances. On Lodgepole pine there were *c.* 0·35 branches per cm of shoot on many coastal provenances, but only 0·25 per cm on inland ones. On Sitka spruce the numbers ranged from 0·60 to 0·85 per cm without any obvious geographic trend.

The degrees of 'apical control' (which influences the growth of lateral branches relative to their parent shoot) and of 'ageing' (which influences the amount of growth any shoot makes as it gets older) were found to be fairly constant within each species.

A model, which used actual measurements of (a) shoot lengths, (b) branch frequencies and (c) estimates of 'apical control' and 'ageing', showed how the numbers of branches, and hence total foliage biomass, increased with changes in each of these variables. It confirmed that variation in (a) and (b) could account for most of the observed variation in shoot growth and branching.

On mature trees of Sitka spruce and Lodgepole pine, the length of the shoots is determined by the numbers of needles that are initiated within the buds the previous year. But what affects the rates and periods of needle initiation? To answer this, buds were removed, at regular intervals throughout one year, from the topmost branches of selected provenances of Sitka spruce (8-years-old) and Lodgepole pine (10-years-old) and counts were made of numbers of primordia that formed during different months. On Lodgepole pine primordia for next year's shoot growth formed within the buds between April and mid-September, whereas in Sitka spruce they formed between May and October. This may be contrasted with the brief period when the pre-formed shoot extends, between late May and mid-July.

Primordia initiation within the buds began earlier in northern, inland and high altitude provenances, than in southerly lowland provenances, which suggested ecotypic differences in response to increasing spring temperatures. The dates when primordia formation ceased were more closely related to the latitudes of the provenance origins, suggesting differences in response to decreasing autumn photoperiods. Thus, the periods of the year when buds formed differed among provenances. But more importantly, there were differences in duration and maximal rates of initiation, which accounted for the differences in total numbers of needles that were produced by shoots on the differing provenances. Furthermore, the differing rates at which primordia were being initiated on any shoot at any time were closely paralleled by the diameters of the apical domes.

M. G. R. Cannell

ASEPTIC CULTIVATION OF TREES

It should be possible to breed trees that are suited to nutritionally poor sites, or that can use nutrients with above average effectiveness; properties that may be genetically controlled. However, in natural conditions these could be obscured by the development of mycorrhizal associations with fungi. To eliminate this complicating factor, specimens of birch, both *Betula verrucosa* and *B. pubescens*, are being grown aseptically in tubes with a nutrient agar medium containing a modification of Ingestad's inorganic salts (Ingestad, 1970). Plants are produced from either surface sterilized seeds or cuttings from aseptic plants, the cuttings being cultured on the standard medium plus naphthalene acetic acid. After being transferred to tubes with the medium amended to test different concentrations of phosphate, plants are incubated at room temperature with standardized lighting conditions. Most experiments last 6–8 weeks when root lengths and numbers, leaf lengths, areas and numbers, stem lengths and component dry weights are measured. By perforating the lids of the tubes so allowing aeration and by improving the selection of clonal plants, mean dry weights have been increased approximately eleven times.

With this technique four clones have been selected for further study – two grow poorly on phosphate deficient media, whereas the others grow relatively well.

J. Pelham P. A. Mason

Reference

Ingestad T. (1970) A definition of optimum nutrient requirements in birch seedlings, 1. *Physiol. Plant.*, **23**, 1127–1138.

ROOT INITIATION AND BUD OUTGROWTH OF *TRIPLOCHITON SCLEROXYLON*

The UK Ministry of Overseas Development and the Nigerian Government have established the West

African Tree Improvement Scheme to help safeguard the range of genetic variation among threatened tree species. The Edinburgh team of ITE scientists is attempting to provide the fundamental back-up for the more applied work being done by the Ibadan team on obeche (*Triplochiton scleroxylon*).

T. scleroxylon has been successfully grown and propagated vegetatively under mist in Edinburgh using heated glasshouses with supplementary lighting. Cuttings with an attached leaf usually rooted readily when air and propagating 'bed' temperatures were 20° and 30°C respectively. Rooting was greatly enhanced when cuttings were dipped in mixtures of naphthalene–acetic and indole–butyric acid but clonal variations were still detectable. For some clones the proportion of cuttings that rooted was increasingly greater as temperatures increased from 24·5° through 29° to 31°C. For others, rooting only occurred at 29°C and 31°C, or 31°C alone.

Material for cuttings is relatively scarce and variable from vertically growing plants. Growing decapitated trees at an angle of 45–50° from the vertical induced bud outgrowth especially at the top and bottom of the stem. The apical shoots developed a branchy habit while the basal ones grew as leading shoots. This technique increased the availability of cuttings and indicated important sources of variation. Cuttings taken from shoots near the decapitated apex were more difficult to root than their basal counterparts. In addition, they also tended to grow horizontally unlike the basal cuttings which grew vertically.

R. R. B. Leakey
V. R. Chapman
K. A. Longman

Plant community ecology

A very large part of the research of the former Nature Conservancy was concerned with plant communities and their response to natural environmental factors and to management. The following reports illustrate the diversity of ITE research on plant ecology. One of the Institute's particular concerns is with vegetation survey. This is also discussed in a later section dealing with the Wash, Maplin, Isle of Man and Shetland projects. M. O. Hill begins this Subdivision's contribution with an account of methodological developments in this field. R. G. H. Bunce and M. W. Shaw have produced a woodland classification based on vegetation, which also correlates other features such as tree cover, habitat and environmental factors. T. C. E. Wells and J. Sheail illustrate the value of historical information in interpreting the kind of site survey ITE expects to do for the Nature Conservancy Council by reference to work at Porton Down. J. E. G. Good and J. M. Way take up other aspects of management-orientated survey in their accounts of work on amenity trees and communication 'fringe habitats'.

The processes in plant communities must be elucidated if we are to predict trends and responses to management and S. B. Chapman and J. Miles discuss aspects of this subject for heather moorland, while D. Welch and R. E. Hughes consider how grazing as a factor alters the composition of vegetation. R. H. Britton describes research on the management of aquatic vegetation at Loch Leven NNR.

In recent years, especially because of the International Biological Programme and Man and Biosphere programme of UNESCO, there has been increasing interest in the modelling of ecosystem processes and this is briefly referred to in a note by A. J. P. Gore on peatlands.

The intrinsic influence of competition has been examined by E. D. Ford and the ecological effects of the herbicide Asulam, increasingly used to control bracken on the uplands, by A. D. Horrill.

THE USE OF INDICATOR SPECIES IN SORTING PLANT SPECIES LISTS

All gardeners know that *Rhododendron* abhors lime. Sundews (*Drosera* spp) are found only in wet places, stonecrops (*Sedum* spp.) only in dry ones. These plants therefore indicate certain environmental conditions. Given a list of species from a particular place, an experienced field botanist, knowing what each of them indicates, can form a picture of the site, and will be able to give some indication of the soil chemistry, soil moisture and other environmental features. The vegetation is effectively a bio-assay of the site.

The problem of vegetation classification is to systematize the experienced field botanist's knowledge, so that it can be clearly communicated to others. Attempts to do this by the ordinary methods of taxonomy have run into difficulties. The worst of these is that there is much intergradation in nature. A sand dune may grade imperceptibly into a marsh. Where should the investigator draw the line? Or should he draw more than one line?

Numerical methods can be of use here. Lists of species can be drawn up, some indicating for example wet conditions, and others indicating dry ones. The moisture status of this site can then be assessed by seeing whether there are more 'wet' than 'dry' species or vice versa. With judicious selection, it may be possible to assess the moisture status of the site with only a few indicator species (we have favoured five or ten).

Staff at the Bangor and Merlewood Research Stations have collaborated in the development of numerical methods of this kind, and have applied them to large sets of data – notably to species lists from 1648 stands in semi-natural woodland. Such large sets of data are most conveniently sorted on a computer, as the human mind boggles when confronted with so much information. Problems still remain but our computer methods can now generate good classifications based on indicator species.

M. O. Hill

CLASSIFICATION OF SEMI-NATURAL WOODLANDS IN BRITAIN

A project on woodland classification was started in 1968 with the main objectives of producing a user-orientated system for the classification of woodland ecosystems and to investigate their underlying environmental relationships. The method of classification is based on the use of artificial keys, analogous to those available in floras, their function being to place samples within a classifying framework that is based upon a series of objectively defined and well-documented types. For the practical conservationist it enables comparisons to be made between woodland sites on a standardized system. Similarly, for the research worker, it provides a means of referencing existing information so that valid extrapolations can be made. It also makes possible the selection of a representative series of sites on which to carry out more detailed research without omission or undue replication. Such studies are also productive in generating ecological hypotheses.

The early stages of the project involved the analysis of species data from over 2000 woodlands throughout Britain. The results were used to provide a limited number of sites (103), encompassing as wide a range of variation as possible within British woodlands. The detailed survey of these sites was carried out in 1971 and recordings were made of vegetation, trees, habitats, soils and other environmental features in sixteen 200sqm plots placed at random in each woodland.

The species data from the survey have now been analysed to produce site keys for the identification of whole woodlands on a cartographic basis and plot keys for the identification of plot types on a scale similar to that used in phytosociological studies. A species classification has also been constructed. This enables different elements occurring within the plot types to be identified, and also the measuring of heterogeneity. The latter is accepted as an integral feature of vegetation which it is the task of the ecologist to understand rather than eliminate from his studies. The rate of mis-classification produced by the simplified keys has been shown to be very low and the classifications can be shown to be very stable. So far, generalization of the classifications to new sites and plots has not revealed any examples which fall significantly outside the range covered by the original survey. Certain parts of the range may require more detailed examination for specific purposes, as has already been done for the native pinewoods of Scotland.

The broad ecological classifications based on vegetation have been used as a basis for the correlation with other features, e.g. tree cover, habitats and environmental factors. All these categories have been shown to be highly correlated with both plot and site types, thus validating the original concept. Standardized descriptions of the main ecological characteristics of the types have been prepared and incorporated with the keys so that the user can classify newly surveyed samples. A handbook providing a guide to the methods, the keys and ecological descriptions, is nearing completion and should be available shortly.

R. G. H. Bunce
M. W. Shaw

ECOLOGICAL STUDIES ON THE PORTON RANGES

Relationships between the vegetation, soils and land use history have been studied on 3333ha of downland within the grounds of the Chemical Defence Establishment, Porton, on the Hampshire/Wiltshire border. During the general vegetation survey, in which six main grassland types were recognized, well-defined changes in the vegetation could be seen, both on the ground and on aerial photographs (see Plate 19). These boundaries were usually linear or enclosed rectangular areas. A study of previous land use and management, using enclosure awards, tithe maps and other historical sources, suggested that these differences in the appearance and composition of the vegetation were related to earlier agricultural activities. A detailed study of the vegetation and soils at seventeen sites revealed that the composition and structure of the grassland types were related to the period which had elapsed since the land was last cultivated, and to the subsequent management of the grasslands. For example, a large area of flint-strewn ground, which supported a lichen-rich grassland of dwarf stature was shown by soil studies to be extremely low in nutrients. This may have resulted from the land being intensively used for cereal production up to about 1870 and then for breeding large numbers of rabbits in a commercial rabbit warren until about 1916.

By comparing the distribution of grassland types, as recorded in the field, with the historical evidence for land-use, it has been possible to assess the rate at which different plant species colonise arable land and the effect of the vegetation on the soil over known periods of time. This information should prove valuable, not only for further autecological studies on important species, but also for providing a time scale whereby the rates of selected fundamental ecological processes can be measured.

The project was undertaken on the Porton Ranges with the kind permission of the Director of the Chemical Defence Establishment, and we gratefully acknowledge the considerable help given to us by Mr B. Whatley, and our colleagues in the NCC.

T. C. E. Wells
J. Sheail

SURVEY OF AMENITY TREES IN THE LOTHIAN REGION

A survey of 870000 trees over 1·8m tall found in Edinburgh made in 1972 showed that over 90% occurred in private gardens. Park and street trees represented only a small fraction of the total. The species of tree varied with location, and the numbers of trees were closely related to the proportion of owner-occupied homes in the differing neighbourhoods.

The Edinburgh survey was made for several reasons, not the least being the need for a baseline when developing a management plan for maintaining reasonable numbers of trees in urban areas. However, amenity trees are not confined to towns and cities; they are major components of our rural landscape. In extending the survey to the former county of East Lothian, it was decided that the term 'amenity' would apply to all trees except those in Forestry Commission forests and woodlands; in woodlands managed under a Dedication or Approval scheme in association with the Forestry Commission; commercial orchards; worked coppice, and hardy stock nurseries. In surveying E. Lothian, random samples were taken from three site categories: (a) urban localities, (b) rural areas less than 164m above sea-level and (c) rural areas more than 164m above sea-level. With the valuable help of Mr H. D. Paterson of the ARC Unit of Statistics, Edinburgh, it was estimated that $2\frac{1}{4}$ million amenity trees, plus or minus a quarter of a million, grew in E. Lothian. The commonest species in category (a) were sycamore, apple, lilac, Flowering cherry and elder; in (b) sycamore, Scots pine, hawthorn, Wych elm and ash, and in (c) birch, Scots pine, larch, beech and hawthorn.

Surprisingly there were fewer amenity trees per hectare in the largely rural E. Lothian than in urban Edinburgh (thirty compared with sixty). Within the county, which is sparsely populated, 19% of amenity trees occurred in gardens which occupy only 1·8% of the land area.

To sustain a timber resource foresters ensure a balanced population of different aged trees with sufficient saplings to fill the gaps created by the removal of mature specimens. The value of an inventory of amenity trees would therefore be greatly enhanced if it included information on age and condition, in addition to numbers of the differing species. As yet we do not have quick and reliable methods for estimating ages of trees growing in the diverse array of amenity sites. Instead we are guardedly extrapolating from size to age, three size classes having been measured; trees 2–5m; 6–10m and greater than 10m in height.

Unhappily our results tend to agree with those of others, suggesting that there is a disturbingly low proportion of saplings to mature trees. In E. Lothian, although the size-class distributions suggest that populations of some species (e.g. sycamore and Wych elm) will be maintained, the data for others (e.g. oak and lime) give cause for concern.

J. E. G. Good

THE ECOLOGY OF LAND ASSOCIATED WITH LINES OF TRANSPORT

Road, rail and inland waterways represent primary land uses; associated with them are significant areas of land whose management costs a significant sum of money but which are, nevertheless, economically unproductive. Areas of this associated land have been calculated on the basis of the wildlife habitat available, although with roads in particular some of this may lie on land belonging to the adjacent owner. Table 2 shows what are considered to be reasonable estimates of the acreages concerned.

This associated land (which has an essential purpose in connection with the primary land use) is properly termed 'ruderal' or waste, but modern connotations of the word 'waste' given an impression of social undesirability which is not true in this context. Although the land is economically unproductive, it has two important secondary functions of (a) general amenity and (b) providing relatively unchanging wildlife habitats, mainly in lowland areas where other habitats are under a continuous process of destruction and change.

It has been a matter of faith with those concerned about wildlife resources that the land associated with roads, railways and canals supports rich and diverse popula-

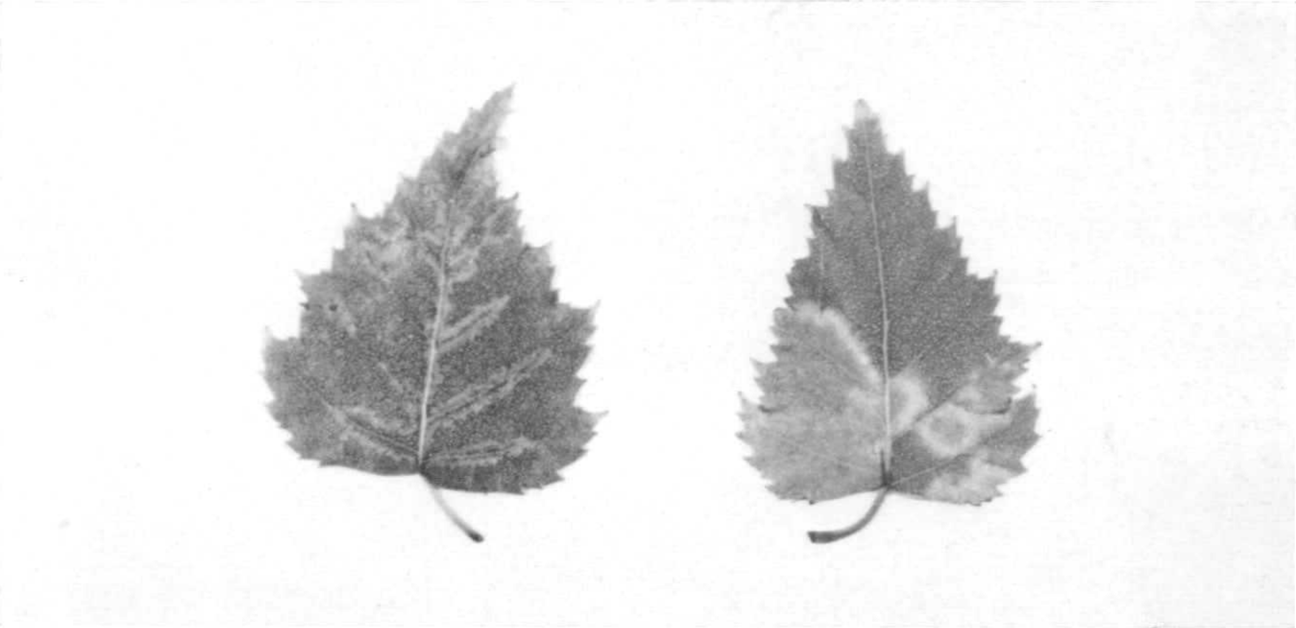
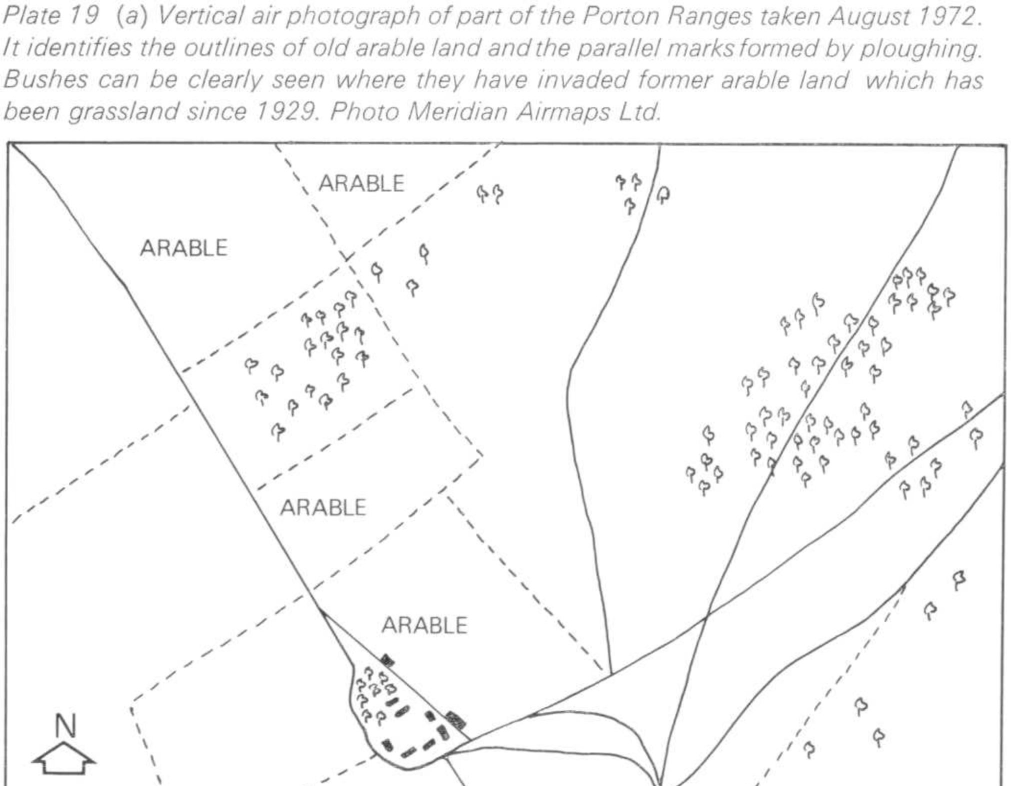


Plate 16 Betula verrucosa *leaves naturally infected with cherry leaf roll virus (CLRV) and showing yellow vein banding or ring pattern. Photograph J. I. Cooper.*

Plate 17 Fraxinus excelsior *leaflet naturally infected with arabis mosaic virus and showing a chlorotic chevron symptom. Photograph J. I. Cooper.*

Plate 18 Fraxinus americana *naturally infected with arabis mosaic virus and showing a distorting mosaic symptom. Photograph J. I. Cooper.*

Plate 19 (a) Vertical air photograph of part of the Porton Ranges taken August 1972. It identifies the outlines of old arable land and the parallel marks formed by ploughing. Bushes can be clearly seen where they have invaded former arable land which has been grassland since 1929. Photo Meridian Airmaps Ltd.



(b) Map based on an air photograph taken in the 1920's, just before the arable land reverted to pasture. The groups of trees have served as progenitors for much of the regeneration that can be seen in the 1972 air photograph of the same area.

Table 2. Approximate number of hectares of land associated with roads, railways and inland waterways. England, Wales and Scotland

Land use	Wildlife habitat	Annually managed grassland
Rural roads	202 500	12 150
Motorways	5 670	
Railways operational	20 250	
disused	20 250	
Navigable inland waterways	4 860	
	253 530 –	(626 000 acres) about 1·1% of the land and water surface of Great Britain

tions of plants and animals. Although County Floras are full of references to records of plants found on roadsides (because they are parts of the countryside that most people first see) there has been no intensive study of these or the other areas, or the management factors and other criteria that have led to whatever actual importance they may have as wildlife habitats.

In order to redress this lack of knowledge a programme of work was begun in 1964 to study the physical features, wildlife resources, conservation importance and management of roadside verges. These were chosen as a matter of priority because of the hazard to wildlife habitats posed by the extensive use of herbicides in the 1950's. This hazard was not so great on the less intensively managed railway and waterway areas.

At the time of writing, two reports (inter alia) have been produced outlining (a) the attitudes and policies of the land managers (County Council Highway departments) towards the management of the areas under their control in 1972 and (b) the liaison existing between County Councils, the Nature Conservancy Council and the voluntary County Naturalists' Trusts over the general management of roadsides for wild plants and animals, and specific arrangements for sites of special conservation importance. Both these reports are considered to be 'base line' documents recording the situation at a point in time against which subsequent developments can be judged. Further reports are in preparation on grassed and planted motorway areas; the results of management experiments together with suggestions for practical programmes of management to satisfy varying standards; and the results of a wide survey of roadsides in England and Wales together with more detailed surveys of individual areas.

The results of the management experiments on roadsides so far published have also proved useful as the basis for advice on the management of other areas of land having similar characteristics.

J. M. Way

LITTER ACCUMULATION UNDER *CALLUNA VULGARIS* ON LOWLAND HEATH

The litter layer accumulating on the soil surface is an important storage bank for plant nutrients that can be released by decomposition. In an ecosystem such as heathland, where such nutrients are present in only limited quantities and where decomposition is slow, the litter layer is important in the overall nutrient regime of the system.

Estimates of litter production that were obtained from the work carried out on the aerial production of *Calluna* were used in conjunction with estimates of litter loss to predict levels of litter accumulation. These predicted levels of accumulation agreed well with direct field observations until about twenty years after a heathland fire, after which they were too low. The apparent discrepancy could be explained in terms of increased weight due to root growth taking place directly within the litter layer.

The release of nutrients from the litter layer has been estimated from differences between the rates of input and accumulation of nutrients within it. Marked increases in the loss of nutrients from the litter are found from the time root invasion of the litter takes place. These results suggest the need for further investigation into the interrelationships between changes in microclimate, associated with increasing age of the heathland vegetation, root growth and possible stimulation of litter decomposition.

S. B. Chapman

Reference

Chapman, S. B., Hibble, J. and Rafarel, C. R. (1975) Litter accumulation under *Calluna vulgaris* on a lowland heathland in Britain. *J. Ecol.*, **63**, 259–271.

NET AERIAL PRODUCTION BY *CALLUNA VULGARIS* ON LOWLAND HEATH

The productivity by dry lowland heath in Dorset where the vegetation is dominated by the Scottish heather (*Calluna vulgaris*) was examined as a supporting programme in the British contribution to the International Biological Programme. This work has now been completed and the net aerial production by *Calluna* estimated by two methods: from the sum of green material, wood and flower production, and from the addition of litter production to annual increments in the standing crop. A method of predicting potential litter production by *Calluna* has been developed and can be used to provide estimates of litter production from single visits to experimental sites. The pattern of growth and the life history of green shoots have been used to explain the apparently anomalous growth pattern of the vegetation in the phase of heathland development following burning. After a fire, net aerial production by *Calluna* rises to about 300 gm^{-2} yr^{-1} after twenty years and then decreases slightly. Other plant species contribute only about 20 gm^{-2} yr^{-1} to the aerial production of the heathland. The reasons why the term 'pioneer' (as used to describe the initial phase of growth of upland heather) is not generally applicable to lowland heather have been given (Chapman, Hibble and Rafarel, 1975), and the term 'post-burn' suggested as being more appropriate to describe the few years that follow a heathland fire on sites in southern lowland Britain.

S. B. Chapman

Reference

Chapman, S. B., Hibble, J. and Rafarel, C. R. (1975) Net aerial production by *Calluna vulgaris* on lowland heath in Britain. *J. Ecol.*, **63**, 233–258.

THE STABILITY OF HEATHER MOORLAND

Much heather moorland is very stable and reverts to woodland slowly even when not burnt or heavily grazed. Experiments on moors in northern Scotland have demonstrated several causes of this stability, though their relative importance varies from moor to moor. The main cause is usually a lack of seed of species that can invade because of the floristic poverty and large area of most moors. Soil infertility also prevents many new species from establishing, even when seed is naturally dispersed over the moors. Nevertheless, experimental sowings of seed of 107 species on three moors showed that, despite the acid and infertile soils, many more species can establish themselves than grow there at present. However, incoming seeds face several obstacles to establishment. The heather canopy, the cryptogram layer below, and the litter and fermentation layers of the soil can each markedly inhibit establishment. Also, the rapidity of vegetative regeneration means that small openings, such as can be created by animal hooves, quickly disappear, and may rarely permit entry of new species from seed. Seed predation can be a further cause of stability: up to 100% losses of experimentally sown juniper and Scots pine seed have been attributed to predation by woodmice (*Apodemus sylvaticus*) or other predators at many moorland sites.

J. Miles

EFFECTS OF GRAZING ON MOORLAND

Since there are many indications that the British uplands will be increasingly utilized for the production of livestock, and the present fairly stable pattern of management may change, knowledge of the impact of particular grazing pressures will be increasingly important. Furthermore, the effects of even the present grazing, by sheep in most hill areas, by cattle on some lower ground, and by deer in the Scottish Highlands, are not properly known. Indeed there has been much speculation, discussion and controversy.

A study was therefore begun in 1969 to follow vegetation trends at a range of sites in north-east Scotland, the numbers of herbivores being continuously monitored. As expected the heavier grazing pressures were found to produce vegetation dominated by dwarf shrubs, largely heather (*Calluna vulgaris*), to change to grassland. At some of the wetter sites unpalatable species, such as Purple moor-grass (*Molinia caerulea*), Mat-grass (*Nardus stricta*) and Moor-rush (*Juncus squarrosus*) spread. The data so far analysed suggest that, biomass for biomass, cattle have more impact than sheep and deer, due, at least in part, to the nature of their dung. The cow 'pats' create niches which are colonized not only by adjacent vegetation but also by propagules dispersed from surrounding areas, or which have passed through the animal.

As the work progressed it became more and more evident that in order to predict the impact of given numbers of animals on a given area of hill we require not only quantitative data on plant–animal relationships of the type obtained, but also better knowledge of the year-long distribution pattern of the different herbivores, and the spatial extent of those densities which induce botanical change.

D. Welch

EFFECTS OF GRAZING ON UPLAND VEGETATION IN SNOWDONIA

A series of experimental exclosures was set up at four sites in Snowdonia between 1956 and 1961. The sites chosen were considered to be representative of the major climatic, soil and altitudinal variants of

Key to Figures 17–19.

▲ no grazing

● winter protected

■ normal grazing

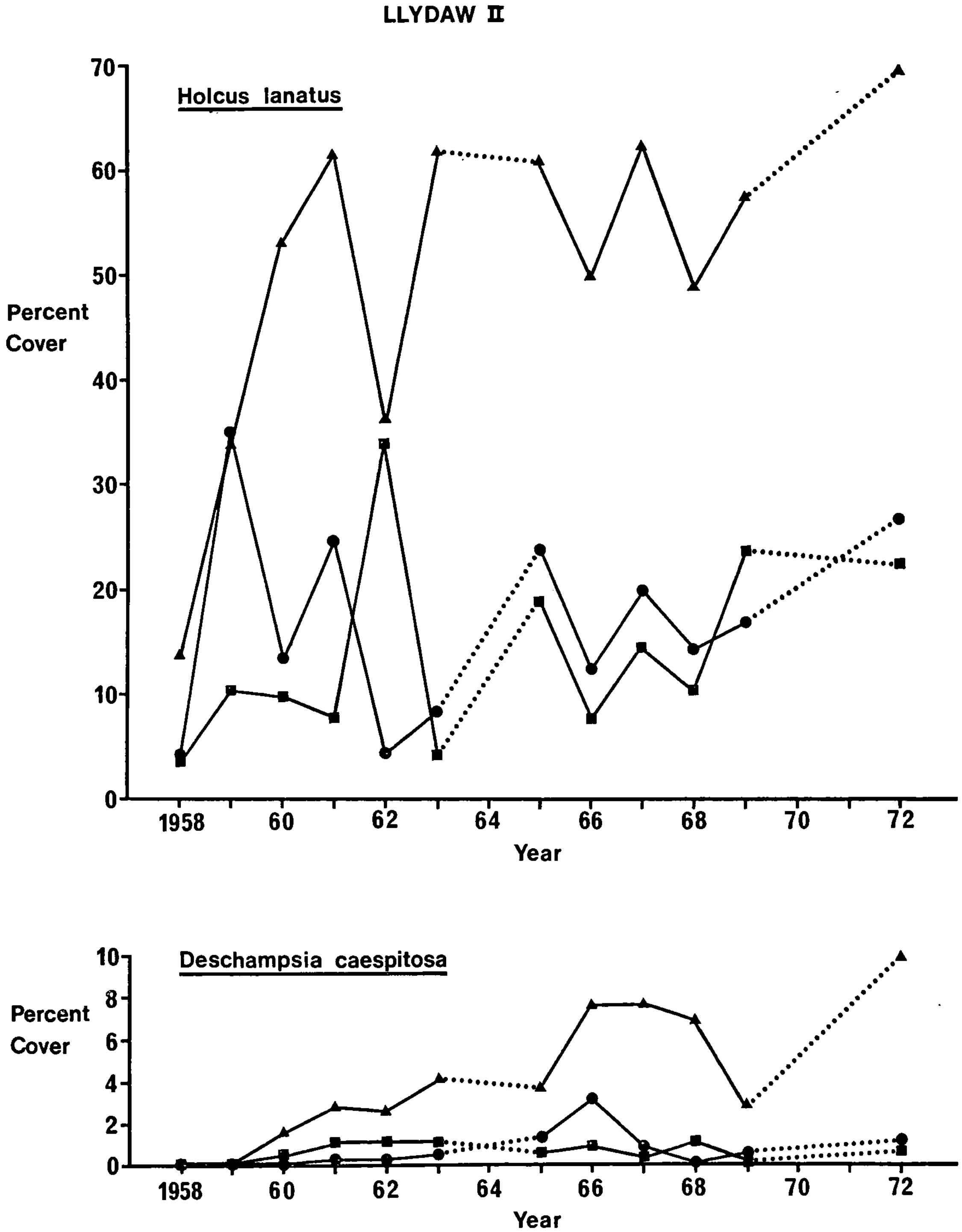


Figure 17 Examples of species change under various grazing regimes.

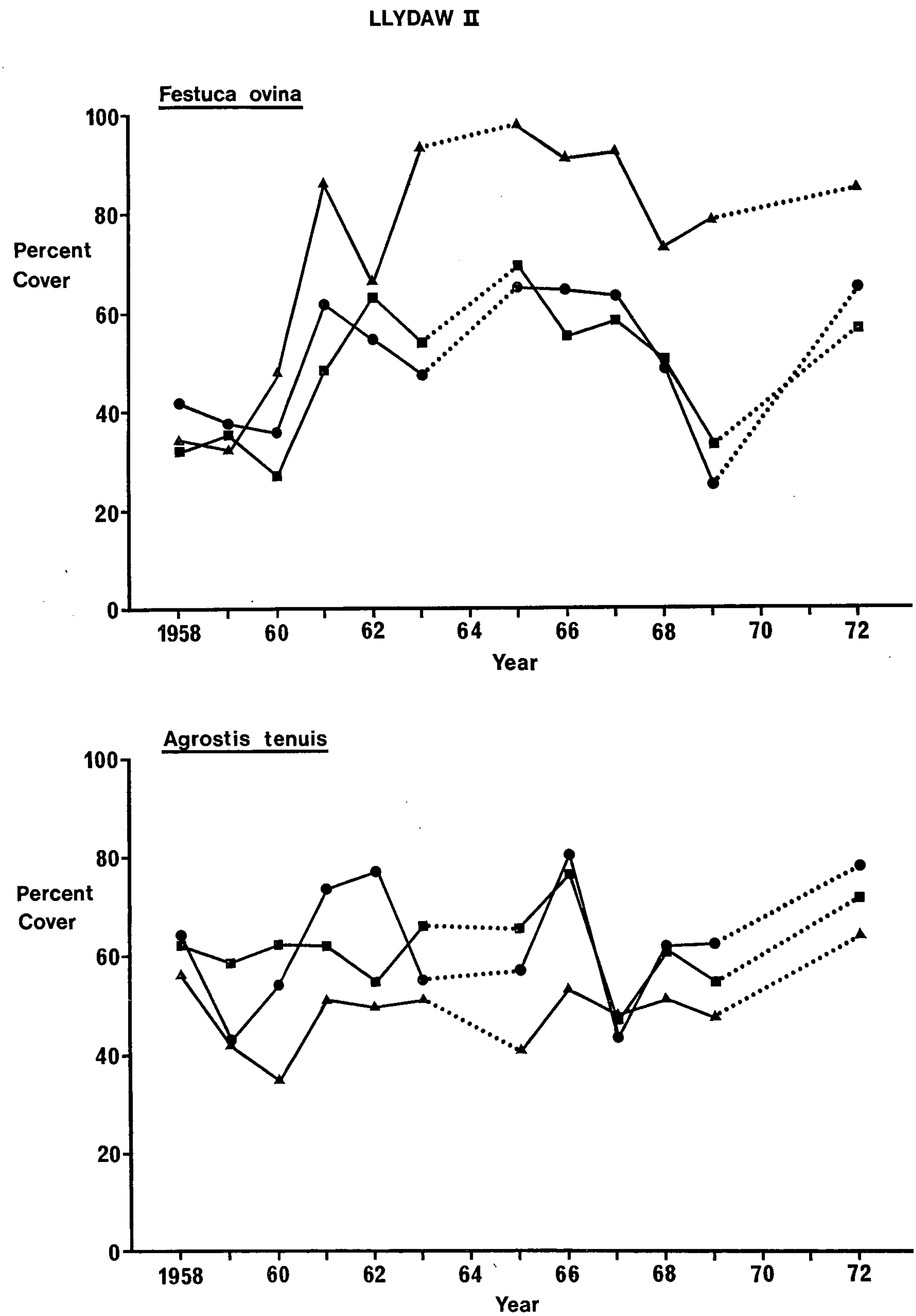


Figure 18 Example of species change under various grazing regimes.

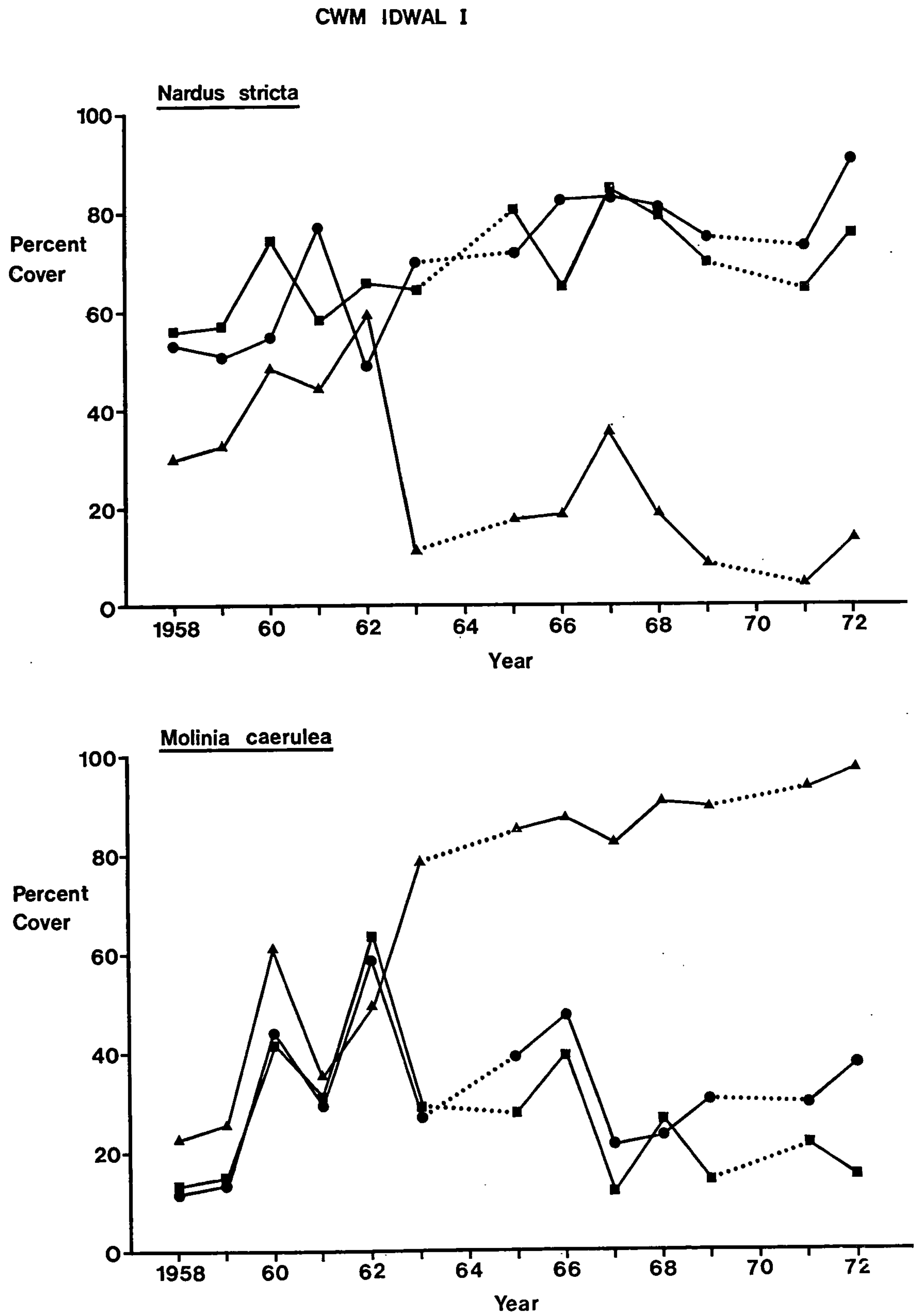


Figure 19 Example of species change under various grazing regimes.

Agrostis/Festuca and *Nardus stricta* grasslands in the area. Three experimental treatments (no restriction of grazing; winter protection from grazing; and absence from grazing) were randomly applied to subplots within each main exclosure at the four sites (see figures 17, 18 and 19).

The absence of grazing caused considerable change in the composition of the vegetation. In general where *Nardus stricta* was formerly the dominant species, *Molinia caerulea* and various heath species have become dominant. On *Agrostis/Festuca* grassland, *Holcus* spp. and *Deschampsia caespitosa* have replaced former dominants. In the absence of grazing, surface litter, soil organic matter and soil moisture all increased. Soil pH showed no definite trend (Dale, 1973).

Subplots which were unprotected, or protected in winter, did not show any noticeable changes in species composition or soil characteristics. The absence of change within the grazed subplots was anticipated since grazing pressure would be the same as that operating outside the experimental areas, the approximate magnitude of which is given in a recent analysis of sheep populations in Snowdonia (Hughes, Dale, Mountford and Williams, 1975). Winter protection from grazing represents an accentuation of the type of management practised in these uplands, where the main grazing flocks are withdrawn for wintering off the mountain and these pastures are virtually ungrazed during the period late October to April.

R. E. Hughes
J. Dale
J. Lutman
A. G. Thomson

References

Dale, J. (1973) Sheep grazing experiments in Snowdonia. *Nature in Wales*, **13**, 229–234.

Hughes, R. E., Dale, J., Mountford, M. D. & Williams, I. E. (1975) Studies in sheep population and environment in the mountains of north-west Wales. II. Contemporary distribution of sheep populations and environment. *J. Appl. Ecol.*, **12**, 165–178.

FACTORS AFFECTING THE DISTRIBUTION AND PRODUCTIVITY OF EMERGENT VEGETATION AT LOCH LEVEN, KINROSS

The study of maps, aerial photographs and other documentary evidence has shown that there has been a decline in the extent of emergent vegetation at Loch Leven. By 1972 only 5% of the shoreline of this shallow productive fresh water loch, and less than 0·01% of its area, was occupied by emergent vegetation, the principal species being the Common reed (*Phragmites communis*) and the Amphibious bistort (*Polygonum amphibium*).

The annual production of Common reed was estimated by harvesting and weighing reeds growing within measured quadrats at the end of the period of summer growth. In terms of area, the production of reed was low for a productive lake, and the total annual production over the whole loch was negligible when compared with that of the planktonic algae and submerged plants.

The construction of netting enclosures and wave barriers showed that grazing by wildfowl, and exposure to wave action were major factors in limiting the present day growth of emergent vegetation. Past grazing by domestic stock, and changes in water level and in the abundance of submerged vegetation probably contributed to the original decline.

R. H. Britton

MODELS OF PEATLAND ECOSYSTEMS

A paper is in press which describes an experiment in which clipping was used to simulate a range of levels of blanket peat vegetation by grazing and burning. Replacement of heather (*Calluna vulgaris*) by Cotton grass (*Eriophorum vaginatum*) was more pronounced on more sloping, shallow peat. Cloudberry (*Rubus chamaemorus*) declined under the more frequent clipping treatment (once per year over 13 years) on the flatter, deeper, and wetter peat, but persisted without appreciable change on a more sloping peat surface. Physical stability of the peat surface possibly contributed to the differences of behaviour of cloudberry but the relatively better growth of the Cotton grass on the steeper slopes may be attributed to an inherently greater availability of mineral nutrients. Local catchment size which possibly controls run-on and aeration of the surface layers due to local slope may both influence mineral nutrition, and are being considered for future research. Models of peat accumulation have already emphasized the importance of surface aeration in determining the rate of peat formation and therefore of organic matter turnover.

A. J. P. Gore

PLANT COMPETITION AND ITS EFFECTS ON STAND STRUCTURE

Monocultures, used widely in agriculture and forestry, produce more even yields than mixtures, and they are easier to manipulate. Nonetheless, considerable differences in plant size tend to develop because of interplant competition, a process occurring 'when the immediate supply of a single factor necessary for growth falls below the demands'. Although this definition is generally held to apply to interactions between a plant and its environment, the effects of competition within variable populations have sometimes been attributed to superior genotype.

Investigations were made of the spatial distribution of plants of different sizes in contrasting plant monocultures, including forests of Sitka spruce and glasshouse plantings of cultivated annuals (*Tagetes* and tomatoes). Although some were genetically heterogeneous and others were homogeneous all populations contained two components: (a) large plants which formed an upper leaf canopy and grew rapidly and (b) small slow growing plants with leaves in a lower canopy. Unexpectedly, plants of the upper canopy were regularly distributed (over-dispersed), suggesting that size was not primarily determined genetically, but was attributable to the effects of competition for light. Competition has then an 'all or nothing effect' resulting in the uniform distribution of large individuals.

E. D. Ford

RESEARCH INTO THE EFFECTS OF ASULAM

Asulam (methyl 4-aminobenzene sulphonyl carbamate) was first prepared by May and Baker in 1961, and initially introduced in Britain for the control of docks (*Rumex* spp.) in pastures. It was subsequently found to be a highly effective agent for the control of bracken (*Pteridium aquilinum*) and was approved for this use in 1972. The mode of action is that the chemical is translocated to the meristematic tissue and prevents bud development in the season following application. Field observations have shown that the majority of fern species are severely affected by the chemical and that several species of higher plants including birch (*Betula* spp.), gorse (*Ulex* spp.), Water lily (*Nuphar* spp.) and some grasses such as *Holcus lanatus* and *Poa trivialis*, experience growth checks. In many areas aerial application is the only practical method, and consequently many non-target plant species and communities get treated.

Investigations at Furzebrook on the role of Asulam as a management tool on heathlands have shown that the majority of plant species, with the exception of gorse, to be unaffected. Continuing work at Bangor and Merlewood is aimed at investigating the toxicological effects of Asulam on upland and woodland species in the field and on selected ferns (*Dryopteris dilatata* and *Blechnum spicant*) and bog species in culture. Ecological changes in plant and animal populations following the eradication of bracken are being followed on sites in Northumberland and North Wales.

A. D. Horrill

Soil science

Research on soils in ITE spans a broad spectrum, from the physical and chemical processes of pedogenesis to the role of organisms in soil, and the effects of soil factors on the micro-organisms, roots and animals living there. Inevitably this research merges into that on invertebrate ecology, plant biology and plant community ecology, and very often a multi-disciplinary approach will be needed. The summaries in this section demonstrate this well.

M. Hornung and A. A. Hatton have been concerned with the weathering of the Whin Sill in northern England, and D. F. Ball with patterned ground in Orkney and Shetland – in both cases demonstrating the influence today of previous climates. The detailed pattern of soils in a lowland woodland, examined by P. A. Stevens, has also been correlated with vegetation. A. F. Harrison has studied phosphorus availability in Lake District woodland soils, and, with D. R. Helliwell, demonstrated that soil condition, and phosphorus status in particular, has a predominant influence on the growth of seedlings of two tree species.

The other end of the spectrum is illustrated by a series of reports on decomposer processes. P. J. A. Howard has investigated the factors affecting weight loss and respiration on woodland litter, J. C. Frankland and A. D. Bailey a serological technique for identifying the mycelium of a woodland fungus important as a decomposer, and O. W. Heal reviews work on the synthesis of International Biological Programme studies of decomposition processes in the tundra. Finally, P. M. Latter and G. Howson report on research on the role of enchytraeid worms in the breakdown of moorland litter.

MINERALOGICAL INVESTIGATION OF WHIN SILL DOLERITE AND OVERLYING SOILS

The investigation concerned deeply altered sections in the igneous rock (dolerite) of the Whin Sill, an important geological feature in northern England, and the soils which overlie them. Most exposures of the dolerite have apparently undergone very little weathering in post-glacial times (*c.* 10000 years), but local outcrops are found with up to 15 m depth of soft, altered rock. A field description of a key site in Teesdale, North Yorkshire, has been given by Hornung and Hatton (1974), and the laboratory work has concentrated on mineralogical studies of the altered rock at this site by optical (including thin-section) and X-ray methods. These studies are enabling the cause of the observed weathering to be interpreted. As in other studies elsewhere in Britain, it appears that there is evidence here for deep pre-glacial weathering under warmer climatic conditions, small remnants of the resulting altered rock having been preserved in geologically favourable localities. This work is increasing our understanding of the geological background of the landforms and sources of soil-parent materials in ecologically important areas of north-eastern England.

A. A. Hatton
M. Hornung

Reference
Hornung, M. and Hatton, A. A. (1974) Deep weathering in the Great Whin Sill, northern England. *Proc. Yorks. Geol. Soc.*, **40**, 105–114.

PATTERNED GROUND FEATURES

On higher hill areas in northern Britain, slight and moderate slopes often show a patterning of micro-relief, or of bare and vegetated ground, usually attributable to frost action, though in some cases caused by wind erosion. Some large-scale features are relics of periglacial conditions during the Pleistocene ice age, especially its closing episodes. Recent and contemporary features give outliers in Britain of habitats that are more widely and strongly developed in colder climates of the world. Descriptive studies have been made of two key areas in Orkney and Shetland (Ball and Goodier, 1974; Goodier and Ball, 1975) where types of patterned ground attributable both to frost heave and sorting, and to severe wind exposure, are well displayed on sites which receive little other disturbance. The two sites are Ward Hill, Hoy; and Ronas Hill, Shetland Mainland, 210km further north. The types of feature that are found elsewhere on the British mainland mountains at altitudes generally above 800–1000m are well developed here at above 400m. In comparing the two sites, both of similar altitude, there is a contrast in the relative development of features attributable to wind and frost. The former are well displayed on both these very exposed hill areas, but the latter, while active on Shetland today, occur as recent but currently inactive relics on Orkney. The only available climatic data do not give an obvious explanation for this difference. Such situations may provide a sensitive basis for monitoring significant changes in regional climate with time.

D. Ball

References
Ball, D. F. and Goodier, R. (1974) Ronas Hill, Shetland: A preliminary account of its ground pattern features resulting from the action of frost and wind. In: *The Natural Environment of Shetland.* Edited by R. Goodier, NCC Edinburgh, 89–106.
Goodier, R. and Ball, D. F. (1975) Ward Hill, Hoy, Orkney: Patterned ground features and their origins. In: *The Natural Environment of Orkney.* Edited by R. Goodier, NCC Edinburgh, 47–56.

WOODLAND SOIL TYPES OF BEDFORD PURLIEUS, CAMBRIDGESHIRE

The woodland of Bedford Purlieus, in north-west Cambridgeshire, has a long recorded history of management, and is of scientific value for its variety of ground flora and insect species. The diversity of the woodland is due to the range of soil types, which in turn largely result from a wide range of parent materials, varying texturally from sand to clay, and chemically from acid to calcareous. A soil map has determined the distribution of soil types in the wood as a basis for ecological study, and has added detail to knowledge of the surface geology, with a delineation of glacial drift remnants and post-glacial deposits that locally overlie the wider exposures of sedimentary rocks of Jurassic age. This survey has been followed by mapping the distribution of important single soil properties, such as pH. The aim is to try to relate these properties to the known distribution of ground flora and shrub layer species, in order to determine the ranges in site conditions occupied by certain 'indicator' species at Bedford Purlieus. From this study one could develop a wider investigation of how far ground flora requirements can be extrapolated from one area to another as an aid to more rapid site assessment. An account of the work was presented at a symposium of the Historical Ecology Discussion Group held at Monks Wood and will appear in the published report of this meeting (Stevens, in press).

P. A. Stevens

Reference
Stevens, P. (In press) Geology and Soils. In: *The Ecology of Bedford Purlieus*. Report of Symposium of Historical Ecology Group, Monks Wood.

PHOSPHORUS AVAILABILITY AND RATE OF ORGANIC PHOSPHORUS MINERALIZATION IN LAKE DISTRICT WOODLAND SOILS

A study of the phosphorus status of soils, usually not more than 20–25cm deep, in ten vegetatively different woodlands in the Lake District has been carried out. Available (isotopically exchangeable) phosphorus contents are low, and averaging $16{\cdot}8\ \mu g\ g^{-1}$ ($5{\cdot}9\ \mu g\ cc^{-1}$) and $13{\cdot}7\ \mu g\ g^{-1}$ ($9{\cdot}0\ \mu g/cc^{-1}$) in 0–5 cm and 10–15cm soils respectively. Mor and Moder soils contain less per unit soil volume (but not per unit soil weight) than mulls in the surface layers, but differences in soils at the 10–15 cm depth are not significant. Seasonal variation in available phosphorus content is marked in 0–5cm soils, being highest in summer and lowest in winter (February and March), but absent from 10–15cm soils. Significant differences in available phosphorus content of soils of the different woodlands could not be detected, because of the large degree of variation found in each woodland.

Table 3. Correlation between rate of RNA mineralization in soils and soil variables*

Variable†	Correlation coefficient
pH	0·632‡
Extractable calcium	0·593‡
Isotopically exchangeable phosphorus	0·503‡
Water-soluble inorganic phosphorus	0·428‡
Extractable inorganic phosphorus	0·673‡
Extractable organic phosphorus	—0·467‡
Extractable organic phosphorus as % total phosphorus	—0·600‡
Total phosphorus	0·598‡
C:P ratio	—0·307§
Extractable inorganic P:extractable organic P ratio	0·402‡

* Prepared by Radiochemical Centre, Amersham
† Per unit soil volume (cc^{-1})
‡ $P < 0{\cdot}001$
§ $P < 0{\cdot}05$

Significant correlations occur in 0–5 cm soils between available phosphorus content and other soil variables, including the day of the year when soil is sampled. The magnitude, and in some cases the sign, of the correlation coefficients depend on whether the variables are expressed in terms of soil weight or soil volume. Approximately 50% and 75% of the variation in available phosphorus, per unit soil volume and per unit soil weight respectively, can be accounted for by these variables.

The rates of organic phosphorus mineralization in a range of 0–5 cm woodland soils have also been determined by following the hydrolysis at 13°C of P^{32}-labelled RNA (average molecular weight 3×10^4) added at 20 µg g^{-1} to soils. The rates of mineralization in fifty soils were correlated significantly with a number of soil variables (Table 3). No significant correlations occurred with soil respiration rates, organic matter, clay or silt contents. The results clearly indicate that the rate of mineralization of the extractable (Olsens bicarbonate) organic phosphorus in soils is an important additional factor affecting the availability of soil phosphorus.

A. F. Harrison

RESPONSES OF SEEDLINGS FROM DIFFERING SEED LOTS OF SYCAMORE AND BIRCH, WHEN GROWN IN A RANGE OF LAKE DISTRICT SOILS

The overall responses of seedlings from six seed lots (three of continental origin) of sycamore (*Acer pseudoplatanus* L.) and four seed lots (one of continental origin) of birch (*Betula pendula* Roth.) to twenty-five markedly different soils from the Lake District are being studied. Seedlings are being grown in pots in a mammal-proof enclosure in the Merlewood grounds.

Preliminary analyses of measurements taken at the end of the first growing season indicated that there were no significant differences in the overall mean height growth of seedlings from the various seed lots of each species. Furthermore the inter-correlations between the height growth of the seedlings from the different seed lots of each species and the soils were high (ranging from 0·932 to 0·974 for sycamore and 0·969 to 0·987 for birch; all significant at $P<0{\cdot}001$). The inter-correlations between the growth of seedlings from seed lots of the two species were also high (ranging from 0·831 to 0·879, significant at $P<0{\cdot}001$). These results indicate that the responses of seedlings of different seed lots of either species are very similar and that the responses of the seedlings of the two species are also remarkably alike.

Table 4. Correlations between height growth of seedlings and soil variables

Variable number	Soil variable	Height of sycamore	Height of birch
1	Loss-on-ignition	0·16	0·23
2	Ext. K. (amm. acet.)	0·13	0·09
3	Ext. K. (acetic acid)	0·12	0·05
4	Ext. Ca (amm. acet.)	0·53†	0·36
5	Ext. Ca (acetic acid)	0·25	0·06
6	Ext. P (Truog)	0·81†	0·85†
7	Ext. P (acetic acid)	0·79†	0·83†
8	Isotopic Exch. P (fresh soil, 30 mins, Exch.)	0·81†	0·86†
9	Isotopic Exch. P (air-dry soil, 30 mins Exch).	0·82†	0·85†
10	Isotopic Exch. P (fresh soil, 18 hours Exch.)	0·84†	0·87†
11	Isotopic Exch. P (air-dry soil, 18 hours Exch.)	0·86†	0·87†
12	Phosphatase activity	0·70*	0·75†
13	Water-soluble P	0·74†	0·80†
14	Ext. Fe (amm. acet.)	—0·18	—0·07
15	Ext. Fe (oxalic acid)	0·06	0·04
16	Ext. Fe (amm. citrate + KCl)	0·07	0·10
17	Total P	0·87†	0·84†
18	Total N	0·33	0·36
19	Ext. Ammonia N (KCl)	—0·10	—0·10
20	Ext. Nitrate N (KCl)	0·41*	0·42*
21	Total Ext. inorganic N	0·02	0·03
22	Percentage stones	0·08	—0·09
23	Soil pH	0·41*	0·13

* Significant at $P < 0{\cdot}05$
† Significant at $P < 0{\cdot}01$

The soils were analysed at the time of maximum growth rate of the plants (mid-late June) for a range of properties and the correlations between mean height growth of all seed-lots of each species were computed (Table 4). All phosphorus variables showed significant relationships with the growth of both species. Apart from these, only extractable nitrate N, pH and extractable calcium (the latter two with sycamore only) gave significant correlations. Orthogonalized regression followed by multiple regression analyses showed that 96·2 and 92·4% of the variation in the height growth of sycamore and birch respectively can be accounted for by seven of the measured soil variables. The variables in order of importance for sycamore were 10, 17, 23, 4, 8, 13 and 19 and for birch were 10, 11, 13, 7, 17, 19 and 14. The results suggest that soil condition, in particular phosphorus status, is far more important than seed lot variation in the establishment of either species.

A. F. Harrison
D. R. Helliwell

FACTORS AFFECTING WEIGHT LOSS AND RESPIRATION OF DECOMPOSING TREE AND SHRUB LITTERS AT MEATHOP WOOD (IBP MAIN WOODLAND SITE)

The aim of these studies was to define the rates of decomposition of leaf litter of tree and shrub species at the Meathop Wood IBP site and to examine the influence of some environmental factors on the process. Leaves of various tree and shrub species, treated with X-rays to kill animals, were allowed to decompose (usually for two years) in the field in open-ended glass tubes containing soil. Hazel, ash, oak, and birch were each studied for three 2-year periods: 1966–68, 1967–69, 1968–70. Apart from hazel, no litter showed significant within-species differences in weight loss with time. Hazel litter showed a significantly lower weight loss in 1967–68, apparently connected with its low moisture content in that period. Hazel litter curls when dry and appears to be rather difficult to remoisten.

Where there were no significant differences in weight loss with time for the same species in different years, the data were pooled. Oak, hazel, birch, lime, and hawthorn litter did not differ significantly. On the other hand, ash and elm differed significantly from the remaining species and from each other.

Throughout, an asymptotic regression fitted the data better than an exponential regression in each case. This is interesting, because most workers use exponential functions to describe litter decomposition. Probably the absence of fauna from our samples accounts for the difference. Each litter showed an initial rapid weight loss for up to 20 days, and it is possible that this contributes to the good fit of the asymptotic regression. Care is needed not to extrapolate beyond the data with this model. In some cases, even the asymptotic regression did not fit the data well during the initial period.

Chemical analyses (C, H, N, loss on ignition) suggested that no significant change of composition of the leaves with time could be clearly detected because of the variability of the material. However, oak, hazel, elm, and lime, showed marked fluctuations in nitrogen content with time. In some cases there were quite large gains in nitrogen, although it is not clear where this nitrogen came from.

Work is in progress on the fitting of a predictive model for respiration as a function of temperature and moisture to the data, and on the influence of (a) soil type (mull or mor) and (b) source of litter (mull or mor site) on weight loss and respiration.

P. J. A Howard

Reference
Howard, P. J. A. and Howard, D. M. (1974) Microbial decomposition of tree and shrub leaf litter 1. Weight loss and chemical composition of decomposing litter. *Oikos*, **25**, 341–352.

THE DEVELOPMENT OF A SEROLOGICAL TECHNIQUE FOR STUDYING A WOODLAND FUNGUS

The permanence and vigour of a woodland depends largely on its nutrition. Unless fertilizers are applied, much of the nutrient is obtained from dead plant materials. Some of the most important organisms involved in releasing nutrients are gill-fungi (Basidiomycetes). The fruit bodies of these fungi can be identified, but the major portion of each fungus is an anonymous weft of fungal threads of mycelium in the plant litter and soil. The activities of individual species cannot be monitored until identification of mycelium is possible. The breakdown of dead plants by one of these Basidiomycetes, the common Milk cap (*Mycena galopus*), has been examined in the laboratory. The immunofluorescence technique is now being developed for the identification of the mycelium in its natural surroundings.

The technique depends on the occurrence of a specific antigen–antibody reaction and its detection with a fluorescent chemical label. The method is used widely in medicine, but its application to soil ecology has been limited to a very small number of organisms. Mycelium of *M. galopus* has been produced in bulk in a liquid medium, then broken up into protein fractions (antigens), and inoculated into rabbits to induce the production of globulin proteins (antibodies). Antibodies, in the antiserum extracted from the rabbits, combined with mycelium of *M. galopus* (homologous antigen)

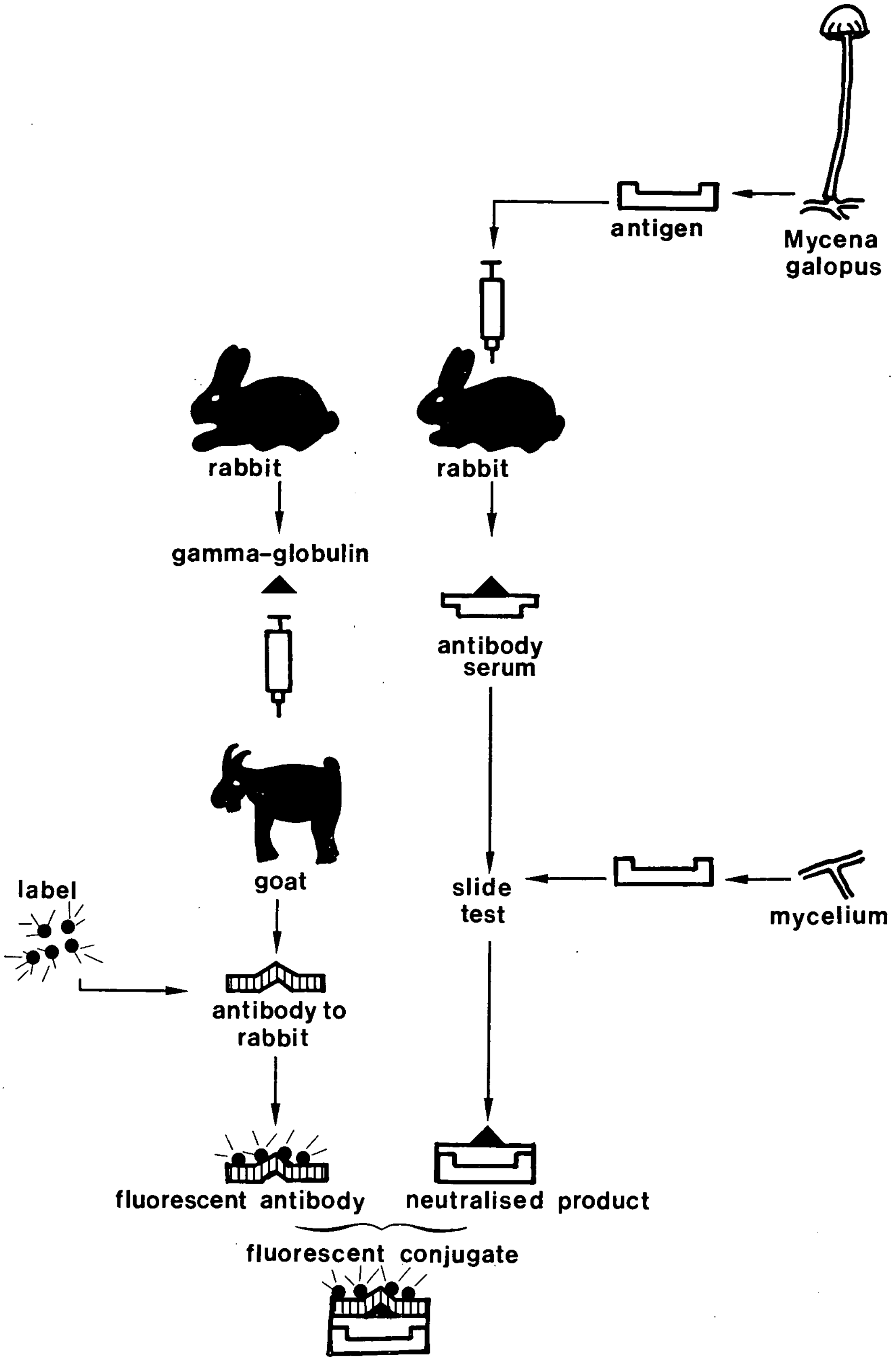


Figure 20 (After Stoward). Use of the indirect fluorescent antibody technique to identify mycelium of Mycena galopus. *Fluorescent label: Fluorescein isothiocyanate.*

to give a positive reaction, both on glass slides and leaf tissue. The indirect method of labelling (Figure 20) was used and the fluorescence of a positive reaction viewed under a fluorescence microscope. The technique is highly sensitive and conditions have to be carefully controlled to avoid spurious results. The antiserum is now being tested for specificity against fungi commonly associated with *M. galopus* on dead leaves. Positive reactions have occurred with some of them, but these cross-reactions have been reduced or eliminated by mixing the antiserum with the mycelium of the black mould, *Cladosporium herbarum.* In this procedure antigens common to both species absorb out cross-reacting antibodies. Even if an antiserum is specific to *M. galopus* in a particular woodland, a number of uncertainties remain. Strains of *M. galopus* may exist elsewhere, with a different antigenic make-up, varying in their ability to decompose plant litter. Pooled antisera may then be required. Again, the distribution of antigen may be usefully related, not just to the identity but also to the actual activity of the mycelium. The ultimate aim is to validate hypotheses on the distribution and activity of the fungus population in different woodlands.

J. C. Frankland
A. D. Bailey

(in collaboration with T. R. G. Gray, Liverpool University and A. A. Holland, Monash University)

DECOMPOSITION IN TUNDRA

The International Biological Programme included a wide range of studies on the decomposition of organic matter in a variety of ecosystems. Moor House National Nature Reserve in the northern Pennines was one of the main sites for ecosystem studies in UK, and because of its sub-arctic climate it was linked with projects in polar and alpine tundra regions of the world, to constitute the Tundra Biome. Results from decomposition studies in eight countries and about forty sites have been integrated to determine the pattern of rates of decomposition and factors controlling these rates. This exercise, involving a number of ITE staff, was stimulated by a grant from the Royal Society and the results have been published (Holding, Heal, MacLean and Flanagan, 1974).

A classification of the sites, using principal component analysis based on soil and climate conditions, was developed to provide an ecological framework for the various biological comparisons. The rates of decomposition, expressed as percentage weight loss per year from plant litters, are usually in the range 0–40%. Simple trends related to gradients of temperature, moisture, soil conditions and chemical composition of the substrate cannot be derived. Within each of these gradients there is as much variation related to the other factors, as to the factor under consideration. Attempts to elucidate the interactive effects of these factors by multivariate, correlative and similar analyses indicated the patterns of change in decay rates. At one extreme, birch twigs at some of the Siberian sites, and *Dryas* in Alaska, showed losses of less than 10%, associated with a high lignocellulose content and cold, dry, oligotrophic conditions. Improvement in one or all of these factors results in increases in the rate of decomposition up to almost 100% per year for leaves rich in soluble carbohydrate, as from Macquarie Island. This is an oceanic, sub-Antarctic site with relatively eutrophic soils and a climate which is warm by tundra standards.

Variation in chemical composition in litters causes considerable variation in decay rate within each site, and comparability between sites was increased by the use of pure cellulose substrates. These pure substrates showed that there was a marked decline in decay rate with depth in some sites, particularly those which were waterlogged or had permafrost. The low decay rates observed in most tundra sites account for the high frequency of organic soils, despite the low levels of primary production.

O. W. Heal

Reference
Holding, A. J., Heal, O. W., MacLean, S. F. and Flanagan, P. W. Eds. (1974) *Soil Organisms and Decomposition in Tundra.* IBP Tundra Biome Steering Committee, Stockholm, 398 pp.

THE ROLE OF ENCHYTRAEID WORMS IN PEAT AT MOOR HOUSE NNR, AND THE DECOMPOSITION OF PLANT REMAINS

The breakdown of dead plant material is essential for the recycling of the contained nutrients and the continued functioning of natural ecosystems. This process should function at a rate which maintains a balance between the accumulation and loss of organic matter. Micro-organisms such as fungi and bacteria are largely responsible for decomposition, while the soil and litter fauna simultaneously eat the dead plant material and micro-organisms. The interactions between the soil fauna and the micro-flora, as well as their effects on the overall decomposition process, are still largely unknown.

The peat of the blanket bog areas at Moor House has accumulated over many centuries. Earthworms are absent from such acid sites, but their ecological niche or place is occupied by enchytraeid worms (pot-worms). The food of the commonest enchytraeid (*Cognettia sphagnetorum*) has been investigated as part of the decomposition studies on this site.

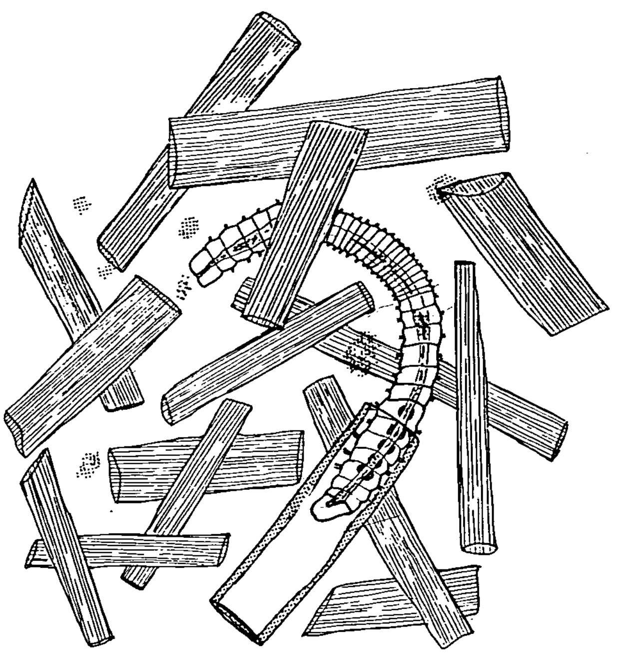


Figure 21 Enchytraeid worm (Cognettia sphagnetorum) *feeding in a test litter.*

The results of field and laboratory tests agree in demonstrating that the worms ingest the older decomposing litter of heather (*Calluna vulgaris* L.), Cotton grass (*Eriophorum vaginatum*) and cloudberry (*Rubus chamaemorus*) (see Figure 21). The micro-organisms are thought to contribute to the release of simpler food constituents, the physical softening of hard tissues, and to the decomposition of toxic products. A basidiomycete fungus is particularly active in these respects. No evidence of the use of micro-organisms as a sole source of food has been obtained, and sterile worms grew on irradiated litter. Parallel studies by Dr V. Standen of Durham University show that the worms and micro-organisms interact to their mutual benefit, since microbial activity was shown to be higher when *C. sphagnetorum* was present in decomposing litter.

The worms select a carbon-rich fraction from the food, and the best growth was shown on foods with higher nitrogen and lower crude fibre content. The worms need a wet environment and their aggregated field distribution results in part from varying moisture content down the profile and the availability of suitable food. Their response to particular management treatments, which increased or decreased their activity, could have long term effects on the accumulation or loss of organic matter on wet moorland sites.

P. M. Latter G. Howson

Data and information

This Subdivision of ITE is concerned with the provision of supporting services in computing, statistics, libraries and with the collection, analysis and dissemination of biological records.

COMPUTERS

The basic policy for computing in ITE depends upon the establishment of small computers at appropriate ITE stations, and the encouragement of all staff to use them, while providing links to larger machines for more specialised or demanding tasks. In pursuance of this policy and as a supplement to the PDP 8/I computer already installed at Merlewood, two in-house computers (PDP 11–10 of Digital Equipment Company) have been installed in ITE during 1974. The first, at Monks Wood Experimental Station, has been operational since March and the second was installed at Brathens Research Station in November. Two-day courses giving instruction in BASIC programming and a general introduction to the use of computers were held at each of these stations. A total of thirty-five staff from all grades received instruction. ITE at the Edinburgh Laboratories, 12 Hope Terrace, has now been linked with the Atlas Computer Laboratory in accordance with NERC computing policy, and a MOP terminal has been operational there since the beginning of the year.

Further development work has taken place on information handling and retrieval systems for use with the time-sharing system on the PDP 8/I. They can now be grouped into three broad categories, namely systems for handling:

(a) administrative and scientific information
(b) management information
(c) scientific data

The administrative system deals with topics such as project staff lists grouped by location and activity whilst the library sub-system has been used to maintain a list of the Institute publications since its establishment.

The management information system can handle data about whole sites or about 1 km grid squares. Several searching procedures have been included in this system for extracting data sets based on selected keywords.

The scientific data banks hold either raw or summary data from sites and experiments. A data bank for handling soil profile data has been presented as Research and Development Paper No. 55 entitled 'Recording soil profile descriptions for computer retrieval'.

A useful contact has been made with the Institute of Geological Sciences and their G-EXEC system – a FORTRAN based data management system. Their system has been explored briefly with a set of test data

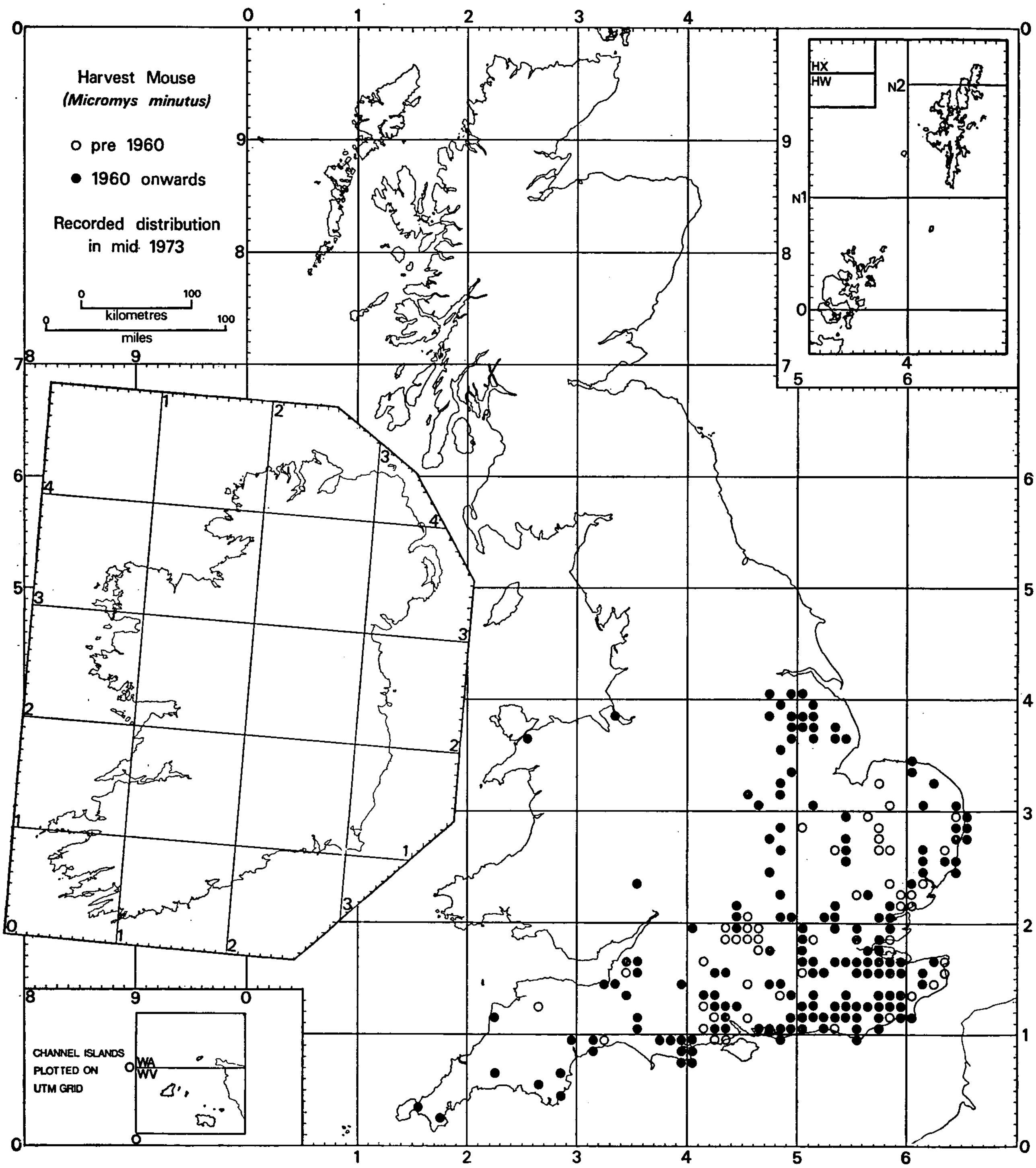


Figure 22 Recorded distribution in mid-1973 of Harvest mouse.

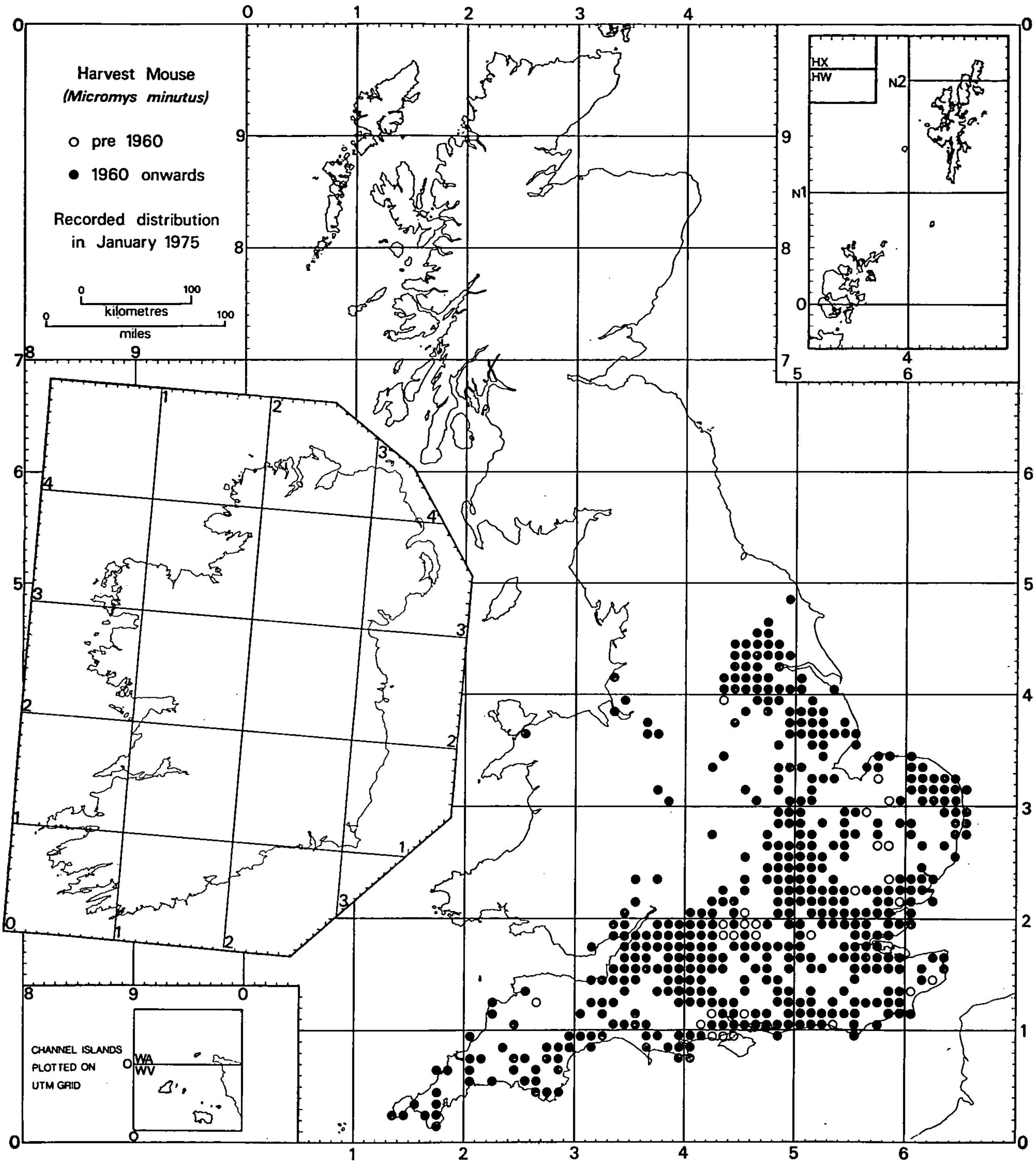


Figure 23 Recorded distribution in January 1975 of Harvest mouse.

with the purpose of finding means of exchanging data between the PDP 8/I and the G-EXEC system on an IBM 370/195.

A. J. P. Gore
D. K. Lindley

BIOLOGICAL RECORDS

The Biological Records Centre has continued its established work of collecting information on the distribution of plants and animals, and has maintained its extensive network of contacts with amateur natural history and conservation bodies. In 1974 there have been some notable developments in the zoological field and these are summarized in the following reports by J. Heath and H. Arnold.

European Invertebrate Survey

All European countries except Albania, Turkey and Iceland are now contributing data to the various schemes being organized by the European Invertebrate Survey (EIS). Three major schemes have their own committees which are represented on the EIS committee. These are the Unitas Malacologica Europaea mollusc scheme, the Odontologica Odonata scheme and the Plant Nematode scheme. Observers from the Committee for Mapping the Flora of Europe and the European Ornithological Atlas Committee also attend meetings of the EIS committee which sends observers to their meetings. Seventeen countries were represented on the committee at the end of 1974, and delegates from twelve of these attended the meeting held in Luxembourg in September.

It is evident from delegates' reports that good progress is being made with national mapping projects in most countries. Germany reported that the first parts of their atlas of Lepidoptera would be published in 1975; Norway that an atlas of Rhopalocera was at press; and Hungary, Yugoslavia and France that data collection had started. Belgium and France have produced atlases of distribution maps for several groups during the year, and Belgium has prepared a coding list for the Aculeate Hymenoptera for all Europe.

The EIS committee forms a network of scientists who can be called upon to provide information quickly on many invertebrate problems. For example, it was able to provide data on the commercial exploitation and conservation of *Helix pomatia* (Roman or Edible snail) throughout Europe for a research project being carried out at Monks Wood Experimental Station.

J. Heath (ITE) continues as Secretary General of this organization and as such attended the fifth European Malacological Congress in Milan in order to report to the Symposium on the progress of EIS in the distribution mapping organized by the Unitas Malacologica Europaea mapping committee.

J. Heath

Insect atlases published and in preparation

Part 3 of the Provisional Atlas of the Insects of the British Isles, Hymenoptera Apidae (bumblebees), has been published. It was edited by Dr D. V. Alford for the Bee Research Association, who organized the data collection with a NERC research grant. This contains dot distribution maps, by 10km squares for all the twenty-six species which occur in the British Isles. These include the parasitic *Psithyrus* species.

Part 4 Siphonaptera (fleas) by R. S. George, has been published. This part will contain maps of all the fifty-nine British species.

An Atlas of preliminary maps of the Orthoptera, Dictyoptera and Odonata was produced by offset duplication in A5 format. This new type of publication which had a restricted distribution to recorders and NCC regional staff has proved to be a very valuable stimulus to our volunteer recorders.

J. Heath

Vertebrate atlases published and in preparation

Amphibians and reptiles: In April 1974, the Provisional Atlas of the Amphibians and Reptiles of the British Isles was published. The atlas contained distribution maps of the twelve native species of amphibians and reptiles, and of two introduced species, namely the Marsh frog and the Edible frog. These maps were compiled from previous records published by R. H. R. Taylor in the *British Journal of Herpetology*, and from many other records gathered as a result of surveys initiated by the Biological Records Centre, and in Ireland by An Foras Forbartha Teoranta. Much of the data on the rare species were gathered during detailed surveys by members of the British Herpetological Society.

These maps show that much remains to be learnt about the distribution of our herpetofauna; in particular, the newt maps showed a patchiness of distribution which must reflect the lack of recorders in some areas. Many more records are needed, and it is hoped that the Breeding Sites Survey, organized by the BHS Conservation Committee will help obtain these. It is intended that this survey should be run by a network of county recorders, their efforts being co-ordinated by the Biological Records Centre.

Mammals: Work continued throughout this period in transferring the Mammal Society's original records to

Plate 20 Zostera beds, Leigh Marsh, Two Tree Island, Leigh-on-Sea. Photograph Meridian Airmaps Ltd.

Plate 21 Trials were carried out to see if the Dwarf eel grass could be successfully transplanted to replace beds that might be lost by development. In the picture the line of duckboards can be clearly seen which allowed turf to be carried across soft mud. Photograph L. A. Boorman.

Plate 22 A special lightweight amphibious vehicle (the Bazooo) was used for collecting samples from the great expanse of mud and sand flats. Photograph D. Kay.

our own data retrieval system, based on the 10km squares of the National Grid. Updated maps of thirty-one species have now been produced; copies of seven of these (Harvest mouse, mole, hedgehog, badger, otter, Yellow-necked mouse and Serotine bat) have been distributed to recorders and members of the Mammal Society as an indication of progress, and as a stimulation to greater efforts.

Special surveys have been organized by the Mammal Society for badger, Harvest mouse, dormouse and otter. The Harvest mouse survey has produced many new records and in the year that it has been operating a great deal has been added to our knowledge of Harvest mouse distribution (see Figures 22 and 23). A similar survey is getting under way on the dormouse and it is hoped that this work will add to our knowledge of one of Britain's lesser known mammals.

It is intended to publish a Provisional Atlas of Mammal Distribution as early as possible in 1976. This will include all records received up to the end of 1975. We therefore hope to encourage our recorders, and anyone else interested, to make an extra effort this year so that this atlas can be as complete as possible.

H. R. Arnold

Chemistry and Instrumentation

ANALYTICAL SERVICES

The Analytical Sections have been created to provide a comprehensive service in analytical chemistry for the Institute's research scientists. The Section based at Merlewood has been responsible for covering most inorganic and natural organic constituents whilst the Monks Wood Section has concentrated mainly on the organic pesticides.

In addition to its ITE commitments, the Analytical Sections have dealt with chemical requirements of the Nature Conservancy Council and some other NERC institutes. Some external work has been carried out on a contract basis.

A few projects have been more demanding than others in their analytical requirements, both in relation to the sample numbers and the unusual nature of the characteristics to be measured. These have included:

a) The Shetland Survey which required the determination of a large range of background mineral elements.
b) The studies concerned with growth culture which resulted in demands for large scale micro-analyses.
c) Investigations into problems of deer nutrition which called for a detailed examination of deer tissue.
d) Pollution incidents which often required the rapid examination of soils, plant material and stream sediments for abnormal concentrations of toxic substances.

RESEARCH AND DEVELOPMENT

There is a continual need for development studies in any analytical laboratory and the ITE Analytical Sections are no exception. In the past year particular attention has been paid to:

a) The problems of water preservation.
b) The application of X-ray fluorescence spectrometry for the examination of biomaterials.
c) Improvements of the methods available for the separation of organophosphorus pesticides.
d) The establishment of a data banking system.

Individual training students have given valuable assistance with some of these problems.

The research project concerned with the taxonomic classification of Scots pine required a more substantial chemical contribution. Studies were carried out into the feasibility of using terpenes as taxonomic characteristics for this species, taking into account spatial, within-tree and seasonal variations. It was first necessary to develop a suitable technique for the separation and identification of the different terpenes by gas chromatography. A Chemical Investigation Group has now been established to deal with problems of this nature and also to co-ordinate other chemical activities in ITE.

A notable event in the latter part of the year was the publication of an analytical handbook prepared by Subdivision staff. This is entitled *Chemical Analysis of Ecological Materials* and is published by Blackwell Scientific Publications of Oxford.

TECHNICAL SERVICES

In the past, under the Nature Conservancy, the development of technical services was arranged independently by stations, according to the immediate needs of the staff at the station. These services are now being co-ordinated throughout the Institute.

Small automatic meteorological units, soil temperature recorders and time lapse camera systems have been constructed in response to an increasing demand for automatic field instruments. Some instruments are rather novel, for example a device for the measurement of internal burrow dimensions and equipment for collecting wind blown soil. At Furzebrook, there has been interest in the development of electronic equipment for sensing acoustic activity of ants.

S. E. Allen

Multidisciplinary studies and surveys

As Section II explains, while the permanent organization of ITE is based on a series of Divisions and Subdivisions related to scientific disciplines, and the majority of the research projects summarized in these pages have been grouped under Subdivisional headings, ecological research is inevitably multidisciplinary and the Institute will retain project groups that bring together scientists from several Subdivisions. Because of the transitional stage in our re-organization, these project groups have not been defined in time for them to be described in this Report, but they will feature prominently in later years, and more and more research is likely to be summarized under Project Group rather than Subdivisional headings.

There are several activities in 1974 which can only be so treated. They have been brought together here. Two involve the synthesis of major components of the International Biological Programme summarized by P. S. Maitland and J. E. Satchell. Five are surveys – of British lakes and reservoirs; of the habitats of the Isle of Man; of the biology of Shetland; of the habitats and ecology of the Wash, in connection with Feasibility Studies for freshwater storage reservoirs; and of the Maplin area.

All these surveys were commissioned (at least in part); the first two by the Nature Conservancy Council who also supported part of the third, and the last two by the Central Water Planning Unit and the Department of the Environment respectively.

The New Agricultural Landscapes project sponsored by the Countryside Commission examined the changing landscape of lowland Britain arising from modern farming methods. M. J. Woodman reports on this project, for which he acted as ecological adviser. B. N. K. Davis has been recording the developing wildlife of pits and quarries as a basis for planning their future use.

INTERNATIONAL BIOLOGICAL PROGRAMME

Loch Leven Symposium

A three-day Symposium on the Loch Leven International Biological Programme Research Project was held at the University of Stirling from 11 to 13 June 1973, and sponsored by the Royal Society of Edinburgh. Papers presented at this meeting covered all major aspects of this project with special emphasis on a description of the ecosystem there, and the main energy flow from solar radiation through plants and invertebrates, to fish and ducks. All papers presented at the Symposium were published together as a single issue of the Proceedings of the Royal Society of Edinburgh in June 1974, edited by Dr P. S. Maitland. This volume contains twenty-five papers covering much of the work done during the IBP period and is available from the Secretary of the Royal Society of Edinburgh.

P. S. Maitland.

The Meathop Wood Project

The Meathop Wood Project, begun in 1965, involved the study of a small area of deciduous broad-leaved woodland in Lancashire, and an attempt has been made to obtain an energy budget for the community and to elucidate carbon and mineral cycling. Estimates have been made of the potential photosynthesis of the dominant tree and shrub species and their net primary production. The rate of litter fall, sub-divided into the various components such as leaves, branches and fruits; root increment and death; and the soil organic matter content were measured. The decomposition of dead wood in the canopy, of litter on the forest floor and of roots in the soil were followed, and the populations of soil animals, fungi and bacteria were examined. The mineral uptake by various plant species was calculated and the mineral content of the incoming rain, the trunk-flow and canopy throughfall, and the leaching of the litter and soil were assessed.

A preliminary account of the work was presented at a symposium of the British Ecological Society in 1974 and revealed a number of gaps in the data and the need for confirmation of experimental findings. This final data checking stage will be completed in 1975. In the last year, intensive effort has been devoted to bringing the decomposition data together into a 'Meathop Decomposition Model' and it is hoped that a volume presenting the results of the whole project will be at press shortly.

J. E. Satchell

INDEX OF BRITISH LAKES AND RESERVOIRS

A count has been made of all the lakes, reservoirs and other water bodies marked on 1:250000 maps, as an initial step in defining the nature and extent of the freshwater resources of Great Britain. The location, and physical features such as depth and area, have been tabulated and will be stored on a computer index. The index will make it possible to list all waters meeting specified conditions of location and physical characteristics. It will not only allow research and experimental work (including biological sampling) to be planned more efficiently, but also make more effective use of existing knowledge. Various tests of the adequacy of the count have been made. These indicate that the index will not normally include water bodies less than 5 ha in area, and only accounts for 10% of all the waters marked on more detailed maps.

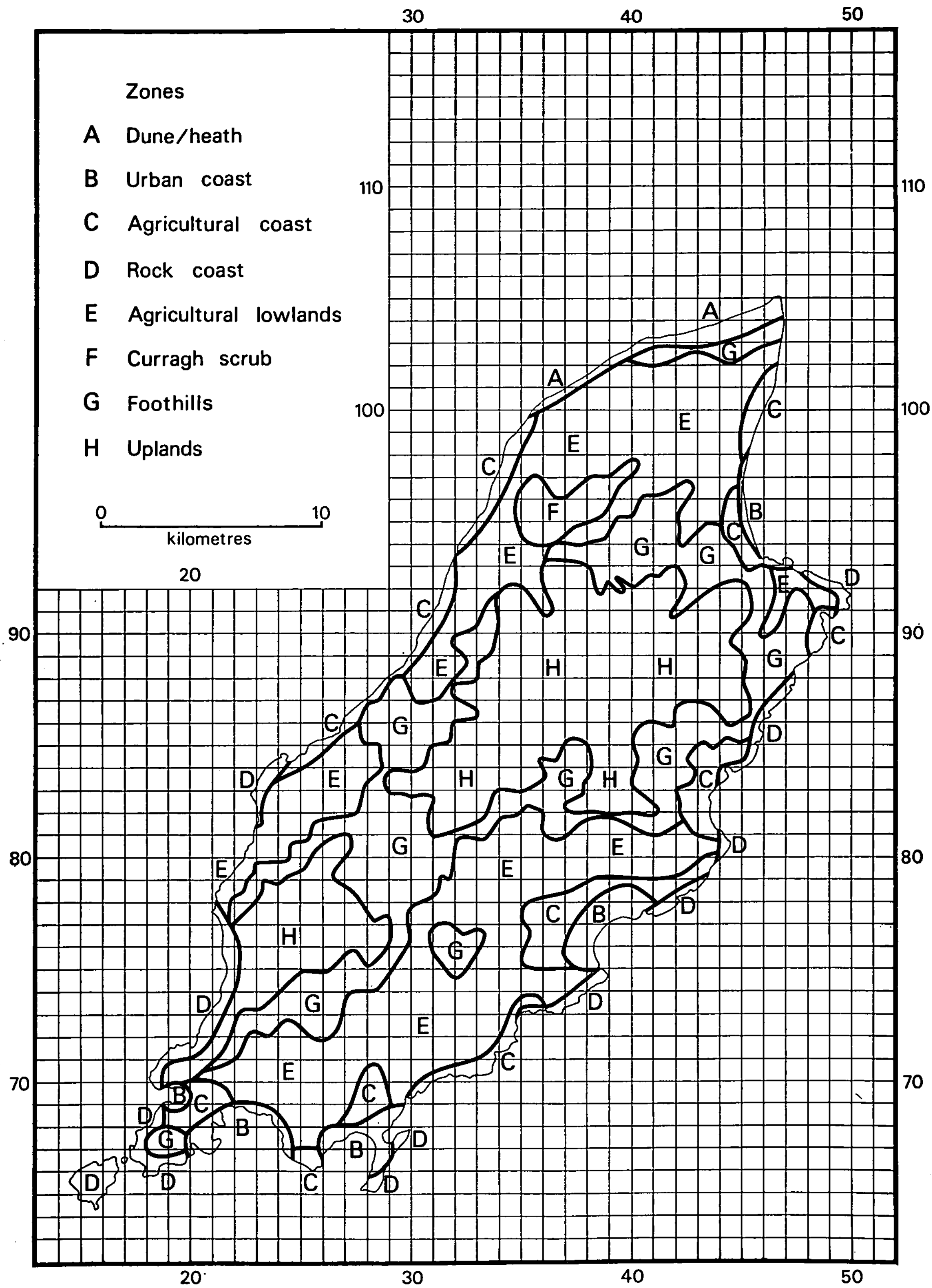


Figure 24 A simplified ecological zonation of the Isle of Man.

The index lists almost 5500 water bodies, roughly one-half of these being in the highlands and islands of Scotland, which cover just over 1% of the area of Britain. As might be expected, the results emphasize the dominance of north-west Britain in terms of quantity. Loch Ness alone, for example, contains more water than all the lakes and reservoirs in England and Wales put together. The relative scarcity of open water in the south and east must obviously influence the direction of future research.

I. R. Smith A. A. Lyle

ISLE OF MAN SURVEY

A survey of the Isle of Man was undertaken by staff at Bangor under contract from the Nature Conservancy Council, on behalf of the Isle of Man Local Government Board. Work began in May 1974 and the main ecological features of the island were examined, using 1:10000 aerial photographs in the laboratory and a sample survey of the coastland, uplands, woodlands and freshwaters in the field during the summer. Graduate students from Salford University were employed by the Institute to assist in the field survey. The interpretation of aerial photographs enabled forty-four habitats to be recorded with a quantitative assessment of their relative frequency and extent. An examination of the relationships between the habitats allowed their ecological grouping and consequent mapping (see Figure 24). The field survey investigated sample areas of the island in greater detail. An analysis of the data so obtained identified the sites of scientific importance on the island. A report of the survey was produced in December and the results used by the Nature Conservancy Council in the preparation of a proposed plan for nature conservation in the Isle of Man.

D. F. Perkins A. Buse

THE SHETLAND PROJECT

The economy of north-west Britain has been traditionally based on the management and use of its renewable natural resources for agriculture, forestry and the fisheries. This has produced a semi-natural environment of considerable stability.

The discovery of oil under the seas around Scotland, and the consequent industrial development for its extraction and utilization, has already made an impact on this environment. Old forms of landuse are being disrupted, and the communities of wild plants and animals associated with them have been placed at risk. The speed and magnitude of the changes make the prediction of their effects extremely difficult. Nowhere is this more acute than on the islands of Orkney and Shetland, which are so close to the main oil and gas fields of the East Shetland basin (see plates 12–15).

ITE and NCC in recognizing this problem have recently completed a project jointly funded, but organized and implemented by ITE, with help from the Marine Biological Association of the United Kingdom (MBA) and the Scottish Marine Biological Association (SMBA). This project assessed the main ecological features of the Shetland archipelago, assembling these data in a flexible, accessible form, in conjunction with the Experimental Cartography Unit (ECU). This initial phase will be followed by a data exploration and mathematical modelling phase to improve prediction of the effects of the new pressures on the environment of Shetland.

Shetland has a long indented coastline on which oil terminal and service facilities are being built. In this situation it is clear that the shore and shallow-sea environments are vulnerable. Considerable efforts have been made to describe the range of physical and biological variation along the Shetland shores, with the aid of MBA and SMBA. The strategy adopted has been to conduct a multivariate analysis of a stratified random sample of shores in Shetland, together with a detailed study of development areas. The different shore types have been classified and a dichotomous key devised for their identification. The geographical distribution of one of these groups is shown in Figure 25. This is a particularly interesting group since it includes all the development sites such as Sullom Voe, as well as the proposed or potential development areas. It seems likely that multivariate techniques of the type used could be valuable in predicting potential development areas generally.

The seabird colonies of Shetland, from Hermaness at the northern tip of Unst to Sumburgh Head at the far south of Mainland, are large and spectacular. They will be particularly vulnerable to oil spills since their birds forage all round the Shetland coasts, and yet they are conspicuous colonial nesters in most cases. They are therefore ideal subjects for a monitoring programme. The survey of the main colonies should provide a useful baseline for future work, but it revealed the difficulties of making useful counts of colonial seabirds. However, some colonies, sections of colonies and some species were easier to census and these have been selected for further work.

Full studies of the terrestrial vegetation and the freshwater ecosystems have also been concluded using the objective multivariate ordination and classification techniques which have characterized the survey. We have felt that objectivity and repeatability combined

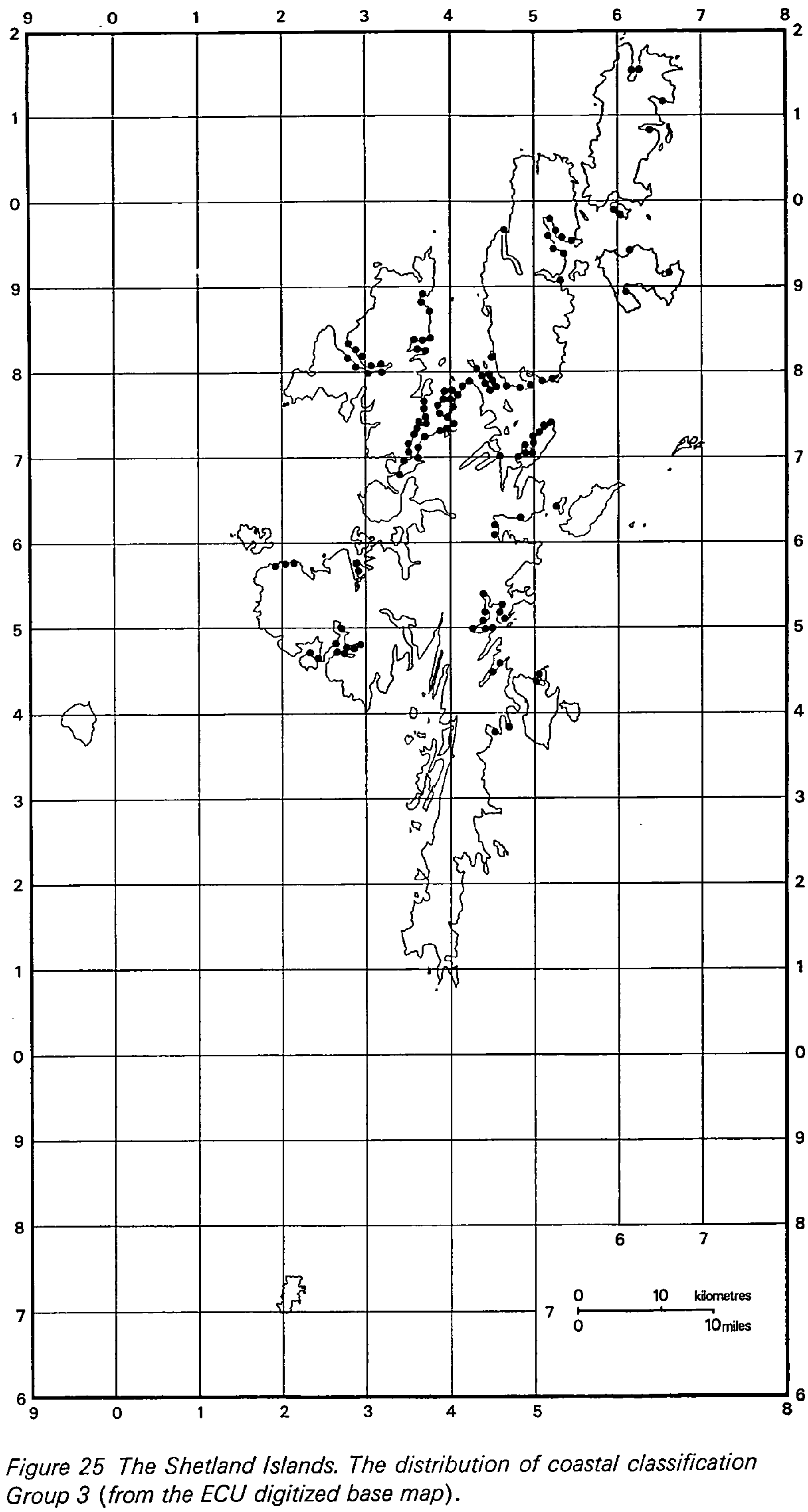


Figure 25 The Shetland Islands. The distribution of coastal classification Group 3 (from the ECU digitized base map).

with statistically sound designs are essential in studying the impact of industrialization on the wilderness areas of northern Britain, since such developments inevitably generate considerable public emotion and interest. ITE has therefore avoided value judgements and concentrated in assembling data for analysis and flexible presentation for others to interpret and use.

C. Milner

THE ECOLOGY OF THE WASH

The Institute undertook ecological studies between April 1972 and February 1975, as a contribution to the Feasibility Study of the proposals for constructing bunded reservoirs for freshwater storage in the Wash.

This work was done by the Natural Environment Research Council under contract to the Water Resources Board, and after that Board's disbandment, the Central

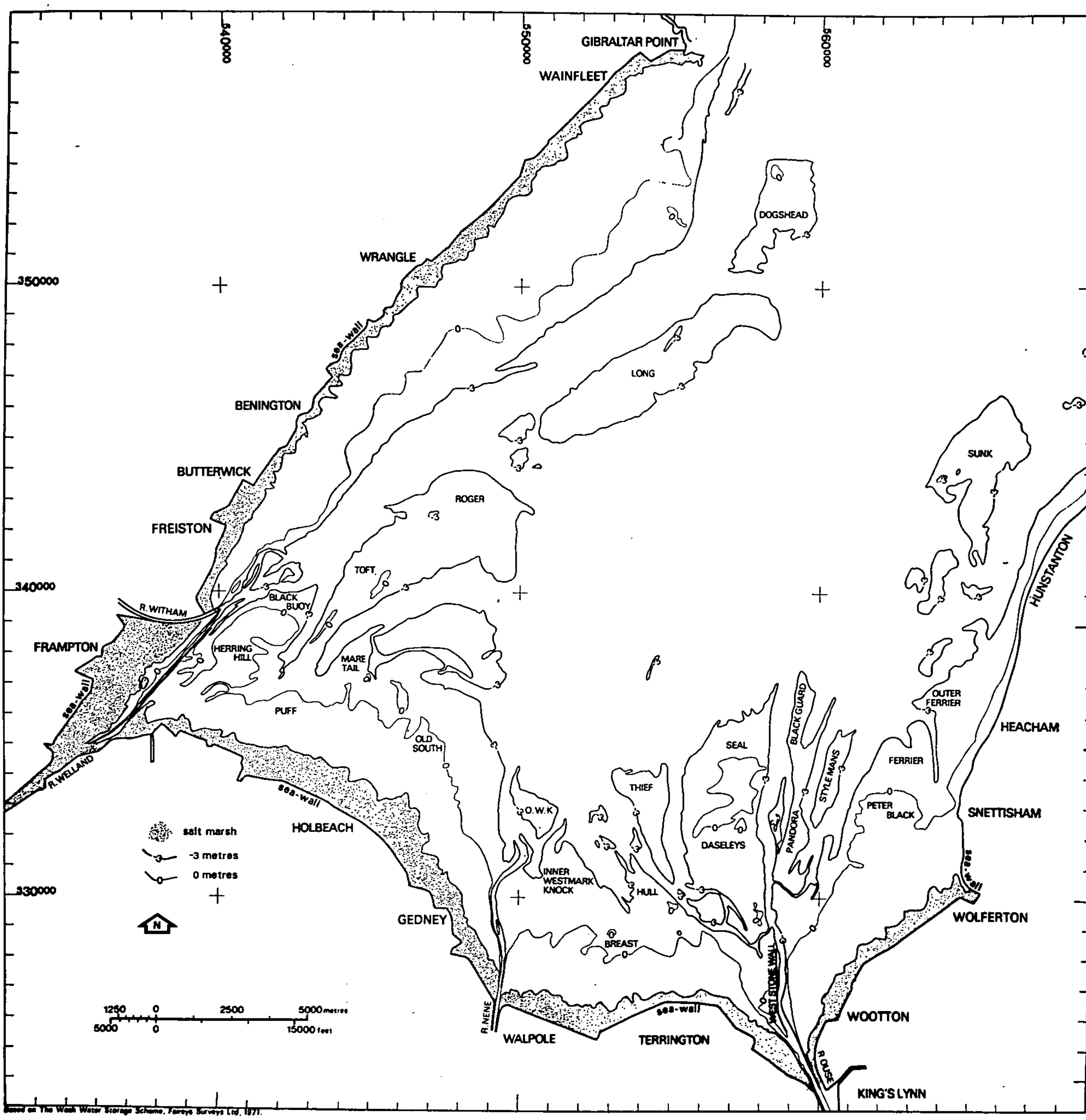


Figure 26 Wash Study Area.

Water Planning Unit. The NERC Institute for Marine Environmental Research (IMER) made a major contribution to the study, and a member of their staff, Mr J. Corlett, co-ordinated contributions on behalf of NERC. MAFF and voluntary natural history and ornithological organizations also made substantial contributions.

The objectives of the work were to describe the pattern of habitats and associated plants and animals in the inter-tidal zones of the Wash; to investigate the processes by which those patterns are governed; and to predict the likely impact upon the ecological systems of the various alternative proposals for storage reservoirs. Particular emphasis was placed on studies of marine fish and shellfish; inter-tidal invertebrates – important as food for wading birds; inter-tidal vegetation and the processes of plant colonization of the mud and sand banks; wading birds and wildfowl; and Common seals. ITE was responsible for the work on vegetation, plant colonization, and waders and their food.

About 280km² of the total 620km² of the Wash are covered by gently-sloping inter-tidal sand and mud flats (see Figure 26). These support large populations of invertebrate animals, whose species and total numbers vary with tidal level and sediment type. On these flats and especially near to the salt marshes which flank their landward limits there are local dense mats of large algae, important as a food for wildfowl, and large numbers of micro-algae whose mucilage secretions have been shown to be especially important in stabilizing fine sediments and allowing levels to build up to the point where salt marsh plants can colonize.

Salt marshes cover about 44km² of the Wash. These marshes are floristically monotonous, but most of them are rapidly accreting and the history of the area is one of extensive reclamation of the upper marshes for agriculture: a process which actually accelerates accretion in marshes lower down. Through this reclamation the Wash today is only two-thirds the size it was in the early 18th century.

The abundant invertebrate fauna of the sand and mud flats supports very large numbers of wading birds, especially in winter when the Wash is one of the two most frequented bays in Britain (the other being Morecambe Bay). There are also numerous wintering shelduck, wild geese, gulls and twite. The breeding bird populations are much smaller, but the area is none the less an important nesting ground for several coastal species.

The Institute is preparing a report on research which defines the main ecological features of the Wash; provides grounds for evaluating the particular impact of the various schemes; and indicates where further research would be of value. It has also provided data for a report on the implication of the schemes for wildlife conservation, which will be submitted by the NCC. These reports together with reports on the engineering, social and environmental aspects will be made available on a common date on completion of the Feasibility Study.

M. W. Holdgate

SURVEYS OF THE MAPLIN REGION

In September 1972, the Department of the Environment placed a contract with the Natural Environment Research Council for an investigation into the ecological implications of the proposal for building a third London Airport at Maplin in Essex.

The studies confirmed that the Maplin Sands area has features of outstanding scientific interest. These features include a very large tract of mud flat, the largest areas in Britain of pioneer marsh covered by the rare Small cord-grass; the largest known continuous bed of Dwarf eel-grass in Britain; a rich invertebrate fauna; and large numbers of wintering wading birds and wildfowl including 20–25% of the world population of the Dark-bellied brent goose (see Plates 20–22).

A series of 'substitute areas' which collectively contain examples of the chief ecological features of Maplin and which might have been utilized if the airport scheme had proceeded has been located. Detailed studies suggest that these sites are already fully used by wintering birds and might not have accommodated the overspill from Maplin unless their carrying capacity was enhanced by management. Research on possible methods for such management has not been carried far enough forward to draw conclusions. Further studies are needed to develop management procedures for coastal nature reserves, and to explore how far ecological changes in the estuaries and coastal zone of the study area are being caused by pollution.

The coastal habitats and the plant and animal associations of 389km² of coast from Felixstowe in Suffolk to Whitstable in Kent have been mapped (see Figure 27). The results of these surveys will be of continuing value to local authorities, the Nature Conservancy Council and the Countryside Commission in forward planning.

L. A. Boorman

THE NEW AGRICULTURAL LANDSCAPES PROJECT

In 1971, the Countryside Commission (England and Wales) sponsored a study by two consultants of the

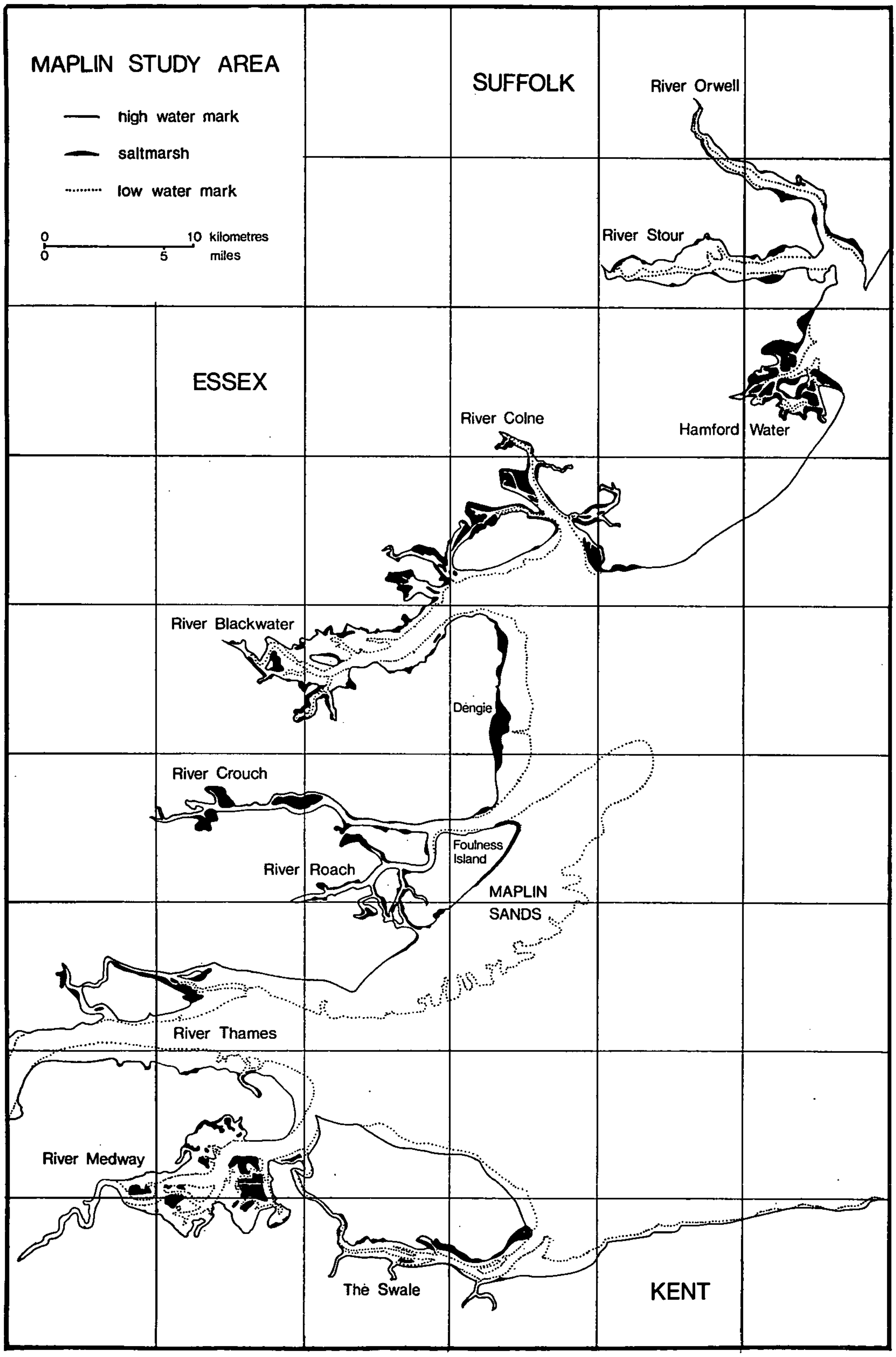


Figure 27 Maplin Study Area.

impact of modern farming on English lowland landscapes. The Nature Conservancy (NC), and later, the Institute, were represented on the advisory committee together with the Commission, MAFF, NFU, Country Landowners Association, and the Institute of Landscape Architects. The NC and ITE were responsible for assessing wild life habitats in the seven study areas which were broadly representative of the different lowland farming types.

The consultants concluded that the old traditional enclosed landscape, although designed for functional reasons, had aesthetic qualities which were now widely valued. The new landscapes arising from large scale agricultural operations were even more functional under today's conditions, but were generally considered to have lost some of the quality. The farmer was primarily concerned with economic agricultural operations, so that landscape features which hampered his work would disappear (see Figure 28). Some that had lost their function might remain if they did not impede farming or cost nothing to maintain. The public's view was based on values which included visual quality, wildlife, access and history. If features with no agricultural value – or even agricultural cost – were to be retained then the farmer could not be expected to shoulder most of the financial burden.

The unproductive areas in predominantly agricultural landscapes appeared to offer a solution to these problems. They fell into two categories, those with natural limits such as steep slopes and streams, and those that were artificial, e.g. ownership boundaries. The consultants proposed that these unproductive areas should be managed to create a network of continuous natural vegetational cover. This could be achieved with minimum harm to agricultural efficiency. The resultant landscape would be attractive though very different from the traditional enclosed landscapes (see Figure 29). If their policy was to succeed, then new approaches to planning and management backed by legislation and financial support would be needed, with government agencies working with farmers and landowners to this end.

ITE is not concerned with the value judgements necessary to decide which, if any, new policies should be advocated. The Countryside Commission have dealt with these issues in a discussion paper which accompanied the publication of the consultants' report. But the Institute's capabilities in the field of survey would allow it to monitor continuing changes in the agricultural landscape, while its ecological expertise could be applied to the development of management techniques for semi-natural vegetation in agriculturally unproductive areas.

M. J. Woodman

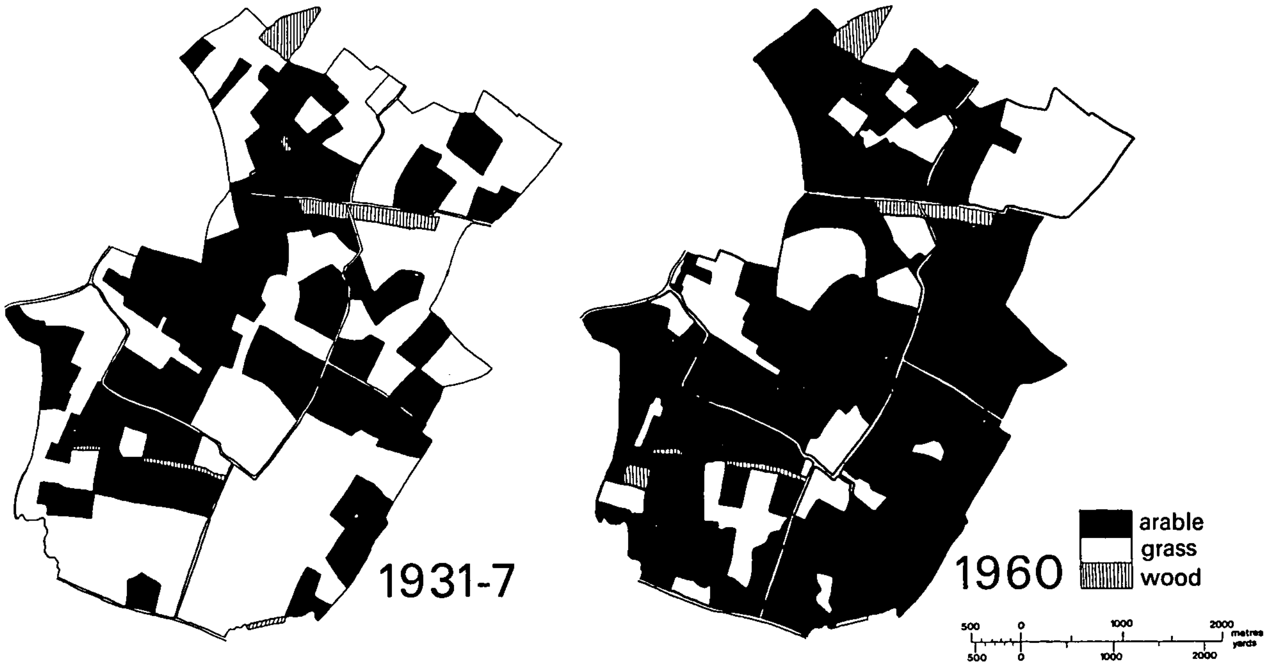
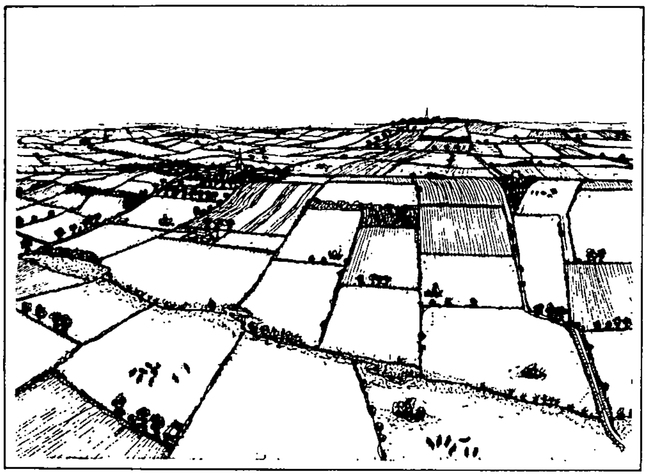
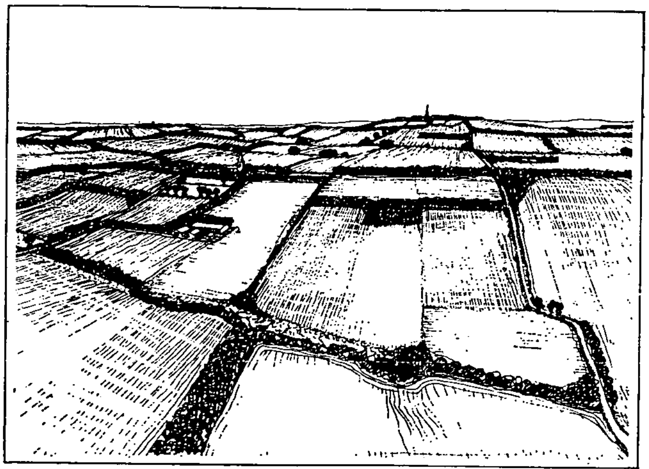


Figure 28 Land use changes in Huntingdonshire Study Area. Reproduced by kind permission of Countryside Commission (England and Scotland).



1945

Today



Consultants' view of future landscape

Figure 29 Agricultural landscape in Huntingdonshire Study Area. Reproduced by kind permission of Countryside Commission (England and Scotland).

ECOLOGICAL EFFECTS OF URBANIZATION AND INDUSTRIALIZATION OF LAND

The wide range of ecological problems created by urban and industrial developments can be divided into three categories. First, there are those associated with urban expansion and the land requirements of industry, especially for mineral extraction; secondly, those resulting from continuous disturbance or pollution in established urban and industrial surroundings; and thirdly, the problems of re-use and rehabilitation of land released from industrial use. A review has been made of this wide field with special reference to nature conservation and this review is now being prepared for publication.

Research emphasis has been placed on studying the development of flora and fauna in pits and quarries. The chalk and limestone industry has been selected for study by ITE, as there is already considerable work being done on gravel pits by other bodies. About 2500 chalk and limestone quarries have been worked in England alone during this century, but no systematic study has been made of their distribution, age, size, physical characteristics, present usage, or biological development.

Lists of quarries which were active about 1950 have been obtained from the Planning, Regions and Minerals Division of the Department of Environment, and samples have been selected for examination. Other sites disused for longer periods of time, and which have become well vegetated, have been suggested by staff of the Nature Conservancy Council, by County Naturalists' Trusts and other individuals. About ninety sites were visited in 1974, mainly in Kent, Derbyshire, Nottinghamshire, Lincolnshire and Norfolk. In the majority of cases records were made of historical, physical and biological details. A standard recording form is being developed for such records so that data can be used in a computer storage and retrieval system for future reference and analysis.

Contracts have been made with the Royal School of Mines and with university departments concerned with the environmental aspects of quarrying. It is considered that the present survey will demonstrate the potential value of revegetated chalk and limestone quarries for conservation and thus help in planning the best after-use of existing old quarries as well as suggesting treatments for newly worked-out sites.

B. N. K. Davis

Section IV

Project list by Stations: 1 April 1975

Monks Wood Experimental Station

ANIMAL ECOLOGY: VERTEBRATE ECOLOGY

291	R. E. Stebbings	Population ecology of bats
292	R. E. Stebbings	Specialist advice on bats

ANIMAL ECOLOGY: INVERTEBRATE ECOLOGY

185	B. N. K. Davis	Effect of urbanization
188	R. C. Welch	Woodland invertebrates
190	P. T. Harding	Woodland invertebrate surveys
201	E. Pollard	The White admiral butterfly
202	E. Pollard	The Roman snail
203	J. P. Dempster	The Cinnabar moth
204	E. Pollard	Assessing butterfly abundance
205	E. Pollard	Invertebrates in hawthorn hedges
229	M. G. Morris	Ecology/taxonomy of Spanish hemiptera
230	M. G. Morris	Cutting experiment (Coleoptera)
231	M. G. Morris	Barton Hills grazing experiment
232	M. G. Morris	Butterfly studies (Porton Range)
233	M. G. Morris	Cutting experiment (Hemiptera)
234	E. Duffey	Grassland management by fire
236	E. Duffey	Invertebrate populations in grass sward
241	L. K. Ward	The fauna of box
243	L. K. Ward	Scrub succession at Aston Rowant NNR
293	L. K. Ward	Study of fauna of juniper
295	L. K. Ward	Survey of juniper in N. England
296	L. K. Ward	Scrub management at Castor Hanglands
309	L. K. Ward	Phytophagous insect data bank
393	J. P. Dempster	The Swallowtail butterfly
399	B. N. K. Davis	Isolated phytophagous insects

ANIMAL ECOLOGY: ANIMAL FUNCTION

176	A. S. Cooke	Toxicology of pollutants
178	J. Parslow	Pollutants in seabirds
179	J. Parslow	Pollutants in estuarine waders
181	A. A. Bell	Birds of prey and pollution
182	J. P. Dempster	Aquatic herbicides
183	A. S. Cooke	Frogs and pollution
193	N. J. Westwood	Stone curlew and lapwing
195	R. K. Murton	Laboratory studies of the Feral pigeon
198	R. K. Murton	Waterfowl reproduction control
199	R. K. Murton	Avian breeding regulation
200	R. K. Murton	The Eared dove in South America
289	F. Moriarty	Pollutants in aquatic animals
290	F. Moriarty	Bulb-dipping as a source of mercury

PLANT ECOLOGY: PLANT COMMUNITY ECOLOGY

184	J. M. Way	Management ecology of transport routes
186	M. D. Hooper	'Island' effect on plant communities
187	M. D. Hooper	Vegetation history from opals in soils
225	T. C. E. Wells	Population studies on orchids
226	T. C. E. Wells	Biology of *Hypochoeris maculata*
227	T. C. E. Wells	Sheep grazing on chalk grass flora
228	T. C. E. Wells	Effect of cutting on chalk grassland
237	T. C. E. Wells	Organic fertilizer effect on grass

242	T. C. E. Wells	Re-establishment of chalk grassland
287	J. Sheail	Landuse history of two fens, East Anglia
288	J. Sheail	Nature conservation in Britain
319	M. J. Liddle	Amenity grassland
348	T. C. E. Wells	Management of MOD areas (Lulworth)
377	J. Sheail	Environmental perception studies

PLANT ECOLOGY: AIR POLLUTION

244	K. Mellanby	Biological indicators of air pollution

SCIENTIFIC SERVICES: DATA AND INFORMATION

206	F. H. Perring	Rare species survey
207	F. H. Perring	Atlas of British flora
208	F. H. Perring	Botanical data bank
209	H. R. Arnold	Amphibians and reptiles survey
210	H. R. Arnold	Mammal distribution survey
211	J. Heath	Lepidoptera distribution maps scheme
212	J. Heath	Odonata distribution maps scheme
213	J. Heath	Orthoptera distribution maps scheme
214	D. W. Scott	Atlas projects
215	F. H. Perring	Biological information network
216	G. L. Radford	Register of NNR's
217	G. L. Radford	Species recording
218	G. L. Radford	Event recording
219	F. H. Perring	BTO ringing returns
220	D. W. Scott	BTO annual ringing analyses
221	D. W. Scott	Internation wildfowl census
222	F. H. Perring	Wildfowl ringing returns
223	J. Heath	European invertebrate survey
224	F. H. Perring	Atlas flora Europaea

Merlewood Research Station

ANIMAL ECOLOGY: VERTEBRATE ECOLOGY

54	V. P. W. Lowe	Red deer ecology on Rhum
56	V. P. W. Lowe	Red deer/Sika taxonomy
57	V. P. W. Lowe	Bark stripping by Grey squirrels
59	V. P. W. Lowe	Taxonomy of the Red squirrel

PLANT ECOLOGY: PLANT BIOLOGY

2	E. J. White	Meteorological factors in classification
3	E. J. White	Meteorological data at Moor House
19	E. J. White	Nutrient input in rainfall
53	A. S. Gardiner	Variation in British woodland trees
58	A. S. Gardiner	Hazel and birch on Shetland
329	E. J. White	Response of Scots pine

PLANT ECOLOGY: PLANT COMMUNITY ECOLOGY

1	R. G. H. Bunce	Semi-natural woodland classification
6	R. G. H. Bunce	Scottish native pinewood survey
9	J. M. Sykes	Monitoring at Stone Chest
10	J. M. Sykes	Monitoring at Kirkconnel Flow

11	J. M. Sykes	Post-fire vegetation at Shieldag SSSI
12	A. D. Horrill	Monitoring in north-west Scotland
13	M. W. Shaw	N.W. England commercial forest survey
14	A. D. Horrill	Tree girth changes in five NNR's
15	A. D. Horrill	Vegetation changes in grazing
16	A. D. Horrill	Bryophyte monitoring in Borrowdale
24	A. H. F. Brown	Meathop meteorology
41	A. J. P. Gore	Primary production – Moor House bog
42	A. J. P. Gore	Plant growth of *Molinia caerulea*
46	D. R. Helliwell	Landscape perception
48	A. D. Horrill	Asulam effects on three upland pastures
50	M. W. Shaw	Defoliation of oak seedlings
55	A. H. F. Brown	Establishment of trees at Moor House
60	D. R. Helliwell	Experimental transplants of *Primula vulgaris*
191	A. Millar	Forest management studies
318	A. J. P. Gore	Peat hydrology
362	R. G. H. Bunce	Multivariate methods
367	A. H. F. Brown	The Gisburn experiment
373	J. M. Sykes	Survey of Wood of Cree SSSI
379	J. M. Sykes	Monitoring at Tyndrum SSSI
387	J. M. Sykes	Juniper regeneration at Tynron NNR
388	J. M. Sykes	Rusland moss survey

PLANT ECOLOGY: SOIL SCIENCE

4	P. J. A. Howard	Soil classification methods
8	A. F. Harrison	Radiocarbon analysis of wood humus
17	J. E. Satchell	Meathop Wood IBP Study
21	O. W. Heal	Decomposition in Meathop Wood
22	J. C. Frankland	Fungal decomposition of leaf litter
23	K. L. Bocock	Soil temperature in Meathop Wood
27	J. C. Frankland	Fungal biomass – Meathop litter and soil
29	A. F. Harrison	Phosphorus circulation
30	J. C. Frankland	Biomass and decay of *Mycena* in Meathop
32	O. W. Heal	Moor House IBP study
33	O. W. Heal	Vegetation decomposition, Moor House
34	O. W. Heal	Radiation and temperature Moor House
39	A. F. Harrison	Phosphorus turnover in soils
40	P. J. A. Howard	Woodland organic matter decomposition
45	O. W. Heal	Tundra biome IBP
51	P. M. Latter	Food consumption of Enchytraeidae
52	K. L. Bocock	Biological studies of *Glomeris*
61	A. F. Harrison	Variation in growth of birch and sycamore

SCIENTIFIC SERVICES: DATA AND INFORMATION

44	D. K. Lindley	Information handling and retrieval
47	C. Milner	Shetland Survey
315	C. Milner	Shetland Survey
365	H. E. Jones	Competition between grass species
376	C. Milner	Statistical training

SCIENTIFIC SERVICES: CHEMISTRY AND INSTRUMENTATION

62	S. E. Allen	National plant nutrient survey
378	S. E. Allen	Chemical data bank

Colney Research Station

ANIMAL ECOLOGY: VERTEBRATE ECOLOGY

67	J. D. Goss-Custard	Prey selection in redshank
68	J. D. Goss-Custard	Dispersion in waders
326	J. D. Goss-Custard	Prey selection in wading birds

ANIMAL ECOLOGY: INVERTEBRATE ECOLOGY

64	S. McGrorty	Intertidal invertebrate surveys
65	S. McGrorty	Invertebrate population studies
66	S. McGrorty	Variation in strandlines

PLANT ECOLOGY: PLANT BIOLOGY

69	R. Scott	Study of *Cakile*
73	A. J. Gray	*Puccinellia maritima*
316	A. J. Gray	Wash Study

PLANT ECOLOGY: PLANT COMMUNITY ECOLOGY

70	L. A. Boorman	Management of sand dunes (E. Anglia)
71	D. S. Ranwell	*Zostera/Spartina* mudflat studies
72	D. S. Ranwell	Salt marsh management
74	D. S. Ranwell	Sand dune stabilization
317	L. A. Boorman	Maplin programme
340	D. S. Ranwell	Coastal surveys in Scotland and Wales
374	L. A. Boorman	Sand dune ecology (E. Anglia)

PLANT ECOLOGY: SOIL SCIENCE

384	S. M. Coles	Benthic microalgal populations

Furzebrook Research Station

ANIMAL ECOLOGY: INVERTEBRATE ECOLOGY

255	G. W. Elmes	Ecology of *Myrmica* species
256	B. Pearson	Protein electrophoresis
257	G. W. Elmes	Queen density in *Myrmica* species
261	B. Pearson	Caste bias in *Myrmica* eggs
262	A. Abbott	Digestive enzymes
270	P. Merrett	Distributional studies on spiders
271	P. Merrett	Spider populations on gorse
272	N. R. C. Webb	Decomposition of *Calluna* litter
273	N. R. C. Webb	Productivity of *Steganacarus magnus*
274	N. R. C. Webb	Soil microbes and soil fauna
275	N. R. C. Webb	Herbivore production on heathland
277	N. R. C. Webb	Moth collection by light trap
278	P. Merrett	Spider population on heather

ANIMAL ECOLOGY: HEATHLAND SOCIAL INSECTS

252	M. V. Brian	Hartland Moor NNR survey
253	M. V. Brian	*Tetramorium caespitum* populations
258	M. V. Brian	Queen effect on larvae growth
259	M. V. Brian	Larvae and worker communication
260	M. V. Brian	Queen recognition by workers
264	M. V. Brian	IBP synthesis volume on ant and termite
370	M. V. Brian	Reduction of inter-species competition
371	M. V. Brian	Male production in *Myrmica*

PLANT ECOLOGY: PLANT BIOLOGY

265	S. B. Chapman	Aerial production of lowland heaths
266	S. B. Chapman	Root production and soil organic matter
267	S. B. Chapman	Organic matter accumulation
268	S. B. Chapman	Ecology of *Erica ciliaris*
269	S. B. Chapman	Effects of soil colour

SCIENTIFIC SERVICES: CHEMISTRY AND INSTRUMENTATION

263	C. R. Rafarel	Worker ant activity
385	C. R. Rafarel	Acoustic communication of *Myrmica*

The Edinburgh Laboratories (Bush)

PLANT ECOLOGY: PLANT BIOLOGY

245	J. Pelham	Genetics of *Betula* nutrition
246	E. D. Ford	Physical environment, forest structure
247	K. A. Longman	Physiology of flowering
248	K. A. Longman	Physiology of root initiation
249	M. G. R. Cannell	Morpho-physiological differences
250	R. C. Warren	Microbial populations on trees
359	M. G. R. Cannell	Fibre yield of poplar coppice
392	M. G. R. Cannell	Potential fibre yield of coppice

PLANT ECOLOGY: PLANT COMMUNITY ECOLOGY

251	J. E. G. Good	Amenity tree survey – Lothians Region
360	J. E. G. Good	Trees on industrial spoil

The Edinburgh Laboratories (Hope Terrace)

ANIMAL ECOLOGY: VERTEBRATE ECOLOGY

116	P. S. Maitland	Freshwater survey of Shetland
117	P. S. Maitland	Freshwater synoptic survey
123	P. S. Maitland	Zoobenthos at Loch Leven
124	P. S. Maitland	Fish distribution and conservation
137	I. Newton	Sparrowhawk research
325	I. Newton	Carrion-feeding birds in Wales

PLANT ECOLOGY: PLANT BIOLOGY

121	M. E. Bindloss	Phytoplankton productivity
125	R. E. Daniels	Peatland monograph
126	R. E. Daniels	Peatland bibliography
127	R. E. Daniels	Mineral utilization
128	R. E. Daniels	Blood moss

PLANT ECOLOGY: PLANT COMMUNITY ECOLOGY

122	R. H. Britton	Loch Leven macrophyte studies

SCIENTIFIC SERVICES: DATA AND INFORMATION

118	I. R. Smith	Lake hydraulics
119	I. R. Smith	Physical limnology

The Banchory Laboratories (Brathens)

ANIMAL ECOLOGY: VERTEBRATE ECOLOGY

104	B. W. Staines	Distribution and segregation of Red deer
105	B. W. Staines	Movements of marked Red deer
106	B. W. Staines	Red deer food studies
107	D. McCowan	Deer movements in Glen Feshie
108	D. McCowan	Red deer populations on Rhum
109	B. Mitchell	Annual cycles in Scottish Red deer
110	B. Mitchell	Red deer population at Glen Feshie
111	B. Mitchell	Population dynamics of Red deer
134	D. Jenkins	Shelducks at Aberlady Bay
138	M. P. Harris	Puffin research
322	D. Jenkins	Aquatic mustelids

PLANT ECOLOGY: PLANT BIOLOGY

79	G. R. Miller	Glen Feshie vegetation
80	G. R. Miller	Red deer grazing of saplings
81	G. R. Miller	Creag Fhiaclach vegetation
82	G. R. Miller	Seed produced by montane plants
99	N. G. Bayfield	Trial of Nature Trail questionnaire
100	N. G. Bayfield	Reseed vegetation on Cairngorm
101	N. G. Bayfield	Vegetation trampling at Cairngorm
102	N. G. Bayfield	Mountain vegetation populations
103	N. G. Bayfield	Dirt roads survey

PLANT ECOLOGY: PLANT COMMUNITY ECOLOGY

83	J. W. Kinnaird	Management for birch regeneration
84	J. W. Kinnaird	Tree age and woodland history, Scotland
85	J. W. Kinnaird	Growth and survival of birch in shade
86	J. W. Kinnaird	Seed production of *Betula pubescens*
91	I. A. Nicholson	Vegetational succession: a review
92	D. Welch	Grazing intensities causing change
93	D. Welch	Assessing animal usage, north-east Scotland
94	I. A. Nicholson	Grazing effect on thirty sites, Scotland
95	D. Welch	Importance of dung in botanical change
96	D. Welch	*Narthecium ossifragum* and burning
112	I. A. Nicholson	Ecology of a Highland deer forest
113	J. W. Kinnaird	Vegetation monitoring at Inverpolly
114	I. A. Nicholson	Forest damage by Red deer
115	I. A. Nicholson	Autecology of *Agropyron junceiforme*
354	D. Welch	Historical research, Moor House grazing
397	I. A. Nicholson	Review of sulphur pollution

PLANT ECOLOGY: SOIL SCIENCE

87	J. Miles	Vegetation potential of upland sites
88	J. Miles	Plant establishment in shrubs
89	J. Miles	*Calluna–Molinia–Trichophorum* management
90	J. Miles	Birch on moorland soil and vegetation

The Banchory Laboratories (Blackhall)

ANIMAL ECOLOGY: VERTEBRATE ECOLOGY

135	N. Picozzi	Research on buzzards
136	N. Picozzi	Hen harrier ecology

ANIMAL ECOLOGY: GROUSE AND MOORLAND ECOLOGY

129	A. Watson	Red grouse and ptarmigan populations
130	A. Watson	Management of grouse and moorlands
131	A. Watson	Golden plover populations
132	A. Watson	Effect of human impact on wildlife

Bangor Research Station

ANIMAL ECOLOGY: VERTEBRATE ECOLOGY

159	D. C. Seel	Upland bird project

ANIMAL ECOLOGY: INVERTEBRATE ECOLOGY

161	A. Buse	Littoral fauna of Llyn Peris
162	A. Buse	Freshwater gastropods in North Wales
338	A. Buse	Role of birds in the spread of NPV (Nuclear Polyhedral Virus)

PLANT ECOLOGY: PLANT BIOLOGY

157	D. F. Perkins	Snowdonia IBP study
158	D. F. Perkins	Community processes (physiology)
160	D. F. Perkins	Pollution studies on Anglesey
166	R. O. Millar	*Hippophae rhamnoides* study
320	D. F. Perkins	Isle of Man survey

PLANT ECOLOGY: PLANT COMMUNITY ECOLOGY

75	D. G. Hewett	Control of *Spartina*
76	D. G. Hewett	Mature shingle beach vegetation, Sussex
77	D. G. Hewett	Cliff vegetation methods
78	D. G. Hewett	Management of sand dunes (Wales)
155	S. D. Ward	Sub-montane plant community key
156	S. D. Ward	Limestone pavement survey
163	M. O. Hill	Ordination and classification methods
165	M. O. Hill	North Wales bryophyte recording
323	M. O. Hill	Comparison of survey methods in USA

PLANT ECOLOGY: SOIL SCIENCE

139	D. F. Ball	Orkney, Shetland patterned ground
140	M. Hornung	Weathering and soil formation, Whin Sill
141	D. F. Ball	Soil chemical variability
142	D. F. Ball	Iron and aluminium in brown podzolic soils
143	M. Hornung	Loessic contribution to Pennine soils
147	D. F. Ball	Soils at Bedford Purlieus
148	M. Hornung	Soil erosion on Farne Islands
151	D. F. Ball	Soils of IBP sites
153	A. A. Hatton	Mineralogical methods
154	M. Hornung	Field recording of profile data

PLANT ECOLOGY: NORTH WEST WALES ECOLOGY

167	R. E. Hughes	Pattern of land occupation
168	R. E. Hughes	Sheep population studies
169	R. E. Hughes	Mollusc survey
170	R. E. Hughes	Arctic/Alpine vegetation survey
171	R. E. Hughes	Bracken control with Asulam
172	R. E. Hughes	Vegetation change with grazing
173	R. E. Hughes	Historical land use studies

174	R. E. Hughes	Snowdonia vegetation map
175	R. E. Hughes	Herpetological studies

ITE Headquarters

395	M. W. Holdgate	Pollutants and their control

ITE Headquarters–Biometrics Group

SCIENTIFIC SERVICES: DATA AND INFORMATION

298	D. Brown	Detecting regular pattern in plane
299	D. Brown	Grouse population model
300	D. Brown	Loch Leven deep water benthos
302	M. D. Mountford	Population growth and regulation
303	M. D. Mountford	Method of cluster analysis
304	M. D. Mountford	Estimation of quantiles
306	P. Rothery	Spatial processes and application
307	P. H. Cryer	Index of egg shell thickness
308	P. H. Cryer	Data from multi-compartment systems
310	D. F. Spalding	Polluted watercourses survey
311	D. F. Spalding	Data definition and validation
312	K. H. Lakhani	Population dynamics of the shrimp
313	M. D. Mountford	Seals research
314	M. D. Mountford	Wytham Wood survey
375	P. Rothery	Theoretical models of diet selection

SCIENTIFIC SERVICES: BIOMETRIC RESEARCH

297	J. G. Skellam	Biometric research

Staff List: 1 June 1975

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Mr W. L. Jones HEO
Miss B. Boyden EO
Mrs W. Chrusciak EO
Mr G. Young EO
Miss C. Ballantyne CO
Mr J. R. W. Hanson CO
Mr S. Hedger CO
Mr C. D. F. Wain CO
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SCIENTIFIC SERVICES

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Mr K. H. Lakhani PSO
Mr D. Brown SSO
Mr P. H. Cryer SSO
Mr P. Rothery SSO
Mr D. F. Spalding HSO
Mrs V. J. S. Worth ASO

Special Merit: Biometrics
Mr J. G. Skellam SPSO

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PLANT ECOLOGY

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Dr S. W. Greene SPSO
Mrs D. M. Greene SSO
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Station Secretary
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Mrs P. M. Marshall CO
Mrs W. A. Morris CO
Mrs J. Pilcher CO
Mrs M. I. Purdy CO (PT)
Mrs C. M. Shackcloth CO
Mrs G. M. Tew CO
Mrs R. M. Cartwright CA
Mrs V. J. Burton Aud/T
Mrs G. J. Sanderson Aud/T
Mrs M. E. Chance Clnr (PT)
Mrs S. Ennis Clnr
Mrs Y. Faulkner Clnr (PT)
Mrs J. McDowall Clnr (PT)
Mrs R. Teat Clnr (PT)
Mrs D. I. Abbott H/Kpr
Mr T. F. Farrington c/Tkr
Mr A. W. Baker E/Wkr

* (PT) denotes part-time.

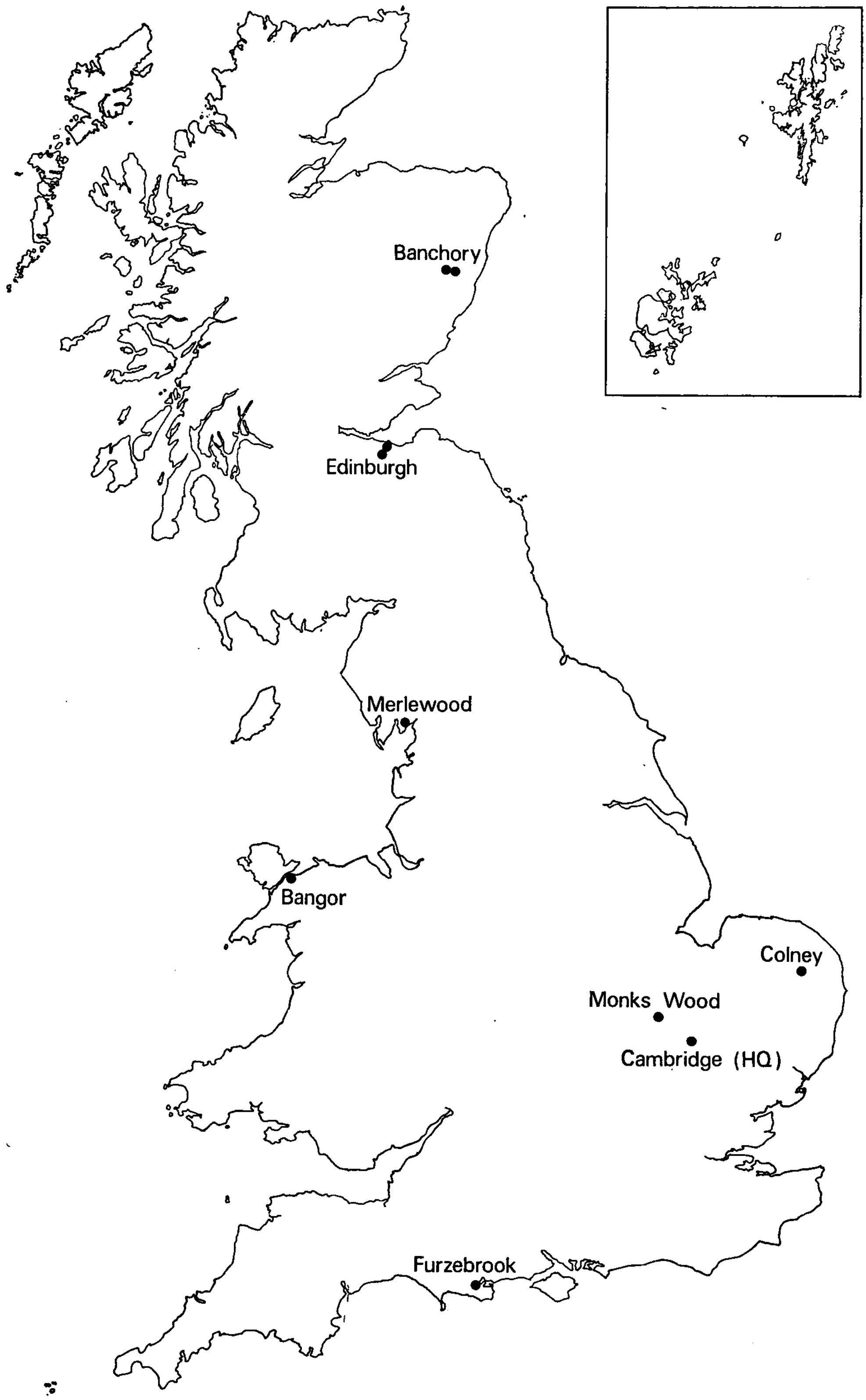

Figure 30 Location of ITE stations in Great Britain.

ANIMAL ECOLOGY

Subdivision of Vertebrate Ecology

Mr R. E. Stebbings SSO

Subdivision of Invertebrate Ecology

Head of subdivision:
Dr M. G. Morris SPSO
Dr B. N. K. Davis PSO
Dr E. A. G. Duffey PSO
Dr E. Pollard PSO
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